SEVENTH FRAMEWORK PROGRAMME

SPECS

Seasonal-to-decadal climate Prediction for the improvement of European Climate Services

GOBIERNO DE ESPAÑA MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

VOLCADEC

ANR MORDICUS

Modulation of the climate response to a volcanic eruption by the Atlantic Multidecadal Variability

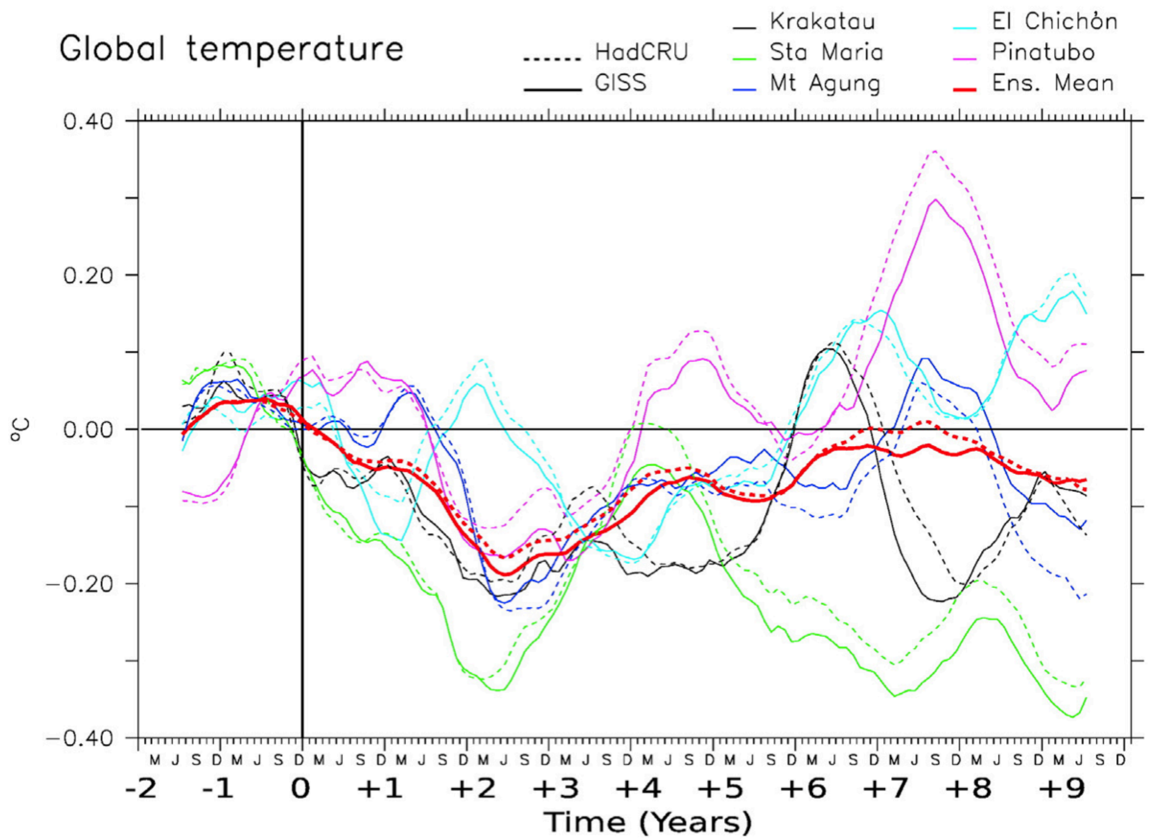
Martin Ménégoz, Christophe Cassou, Didier Swingedouw, Francisco Doblas-Reyes

AMOC conference, Brest, May 2017

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Introduction

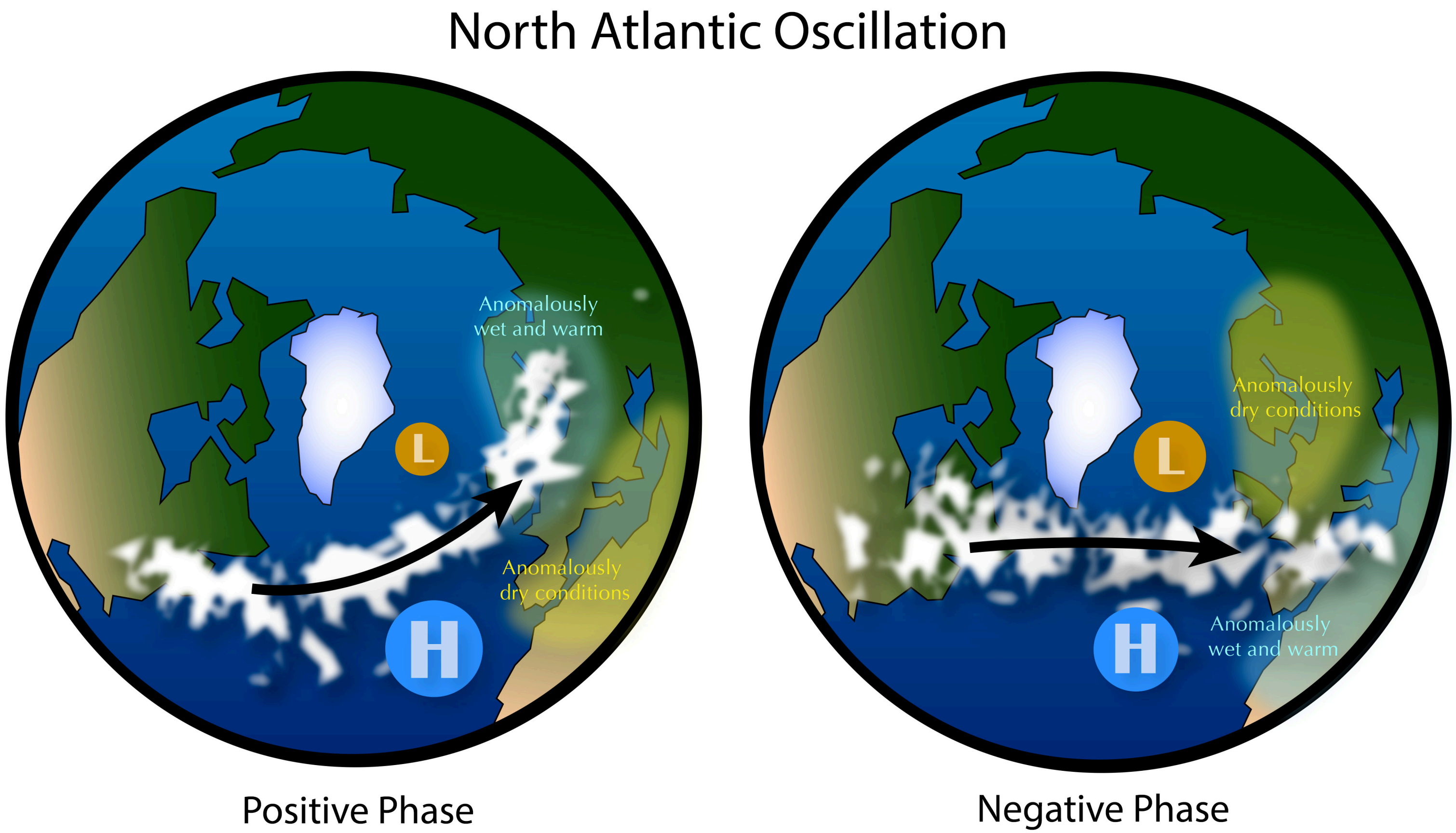
→ Global cooling observed after large volcanic eruptions



(Swingedouw et al., 2017)

Introduction

→ **The NAO is the main mode of climate variability in the North Atlantic**



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Introduction

→ Positive NAO conditions observed during the two winters following the Pinatubo eruption…

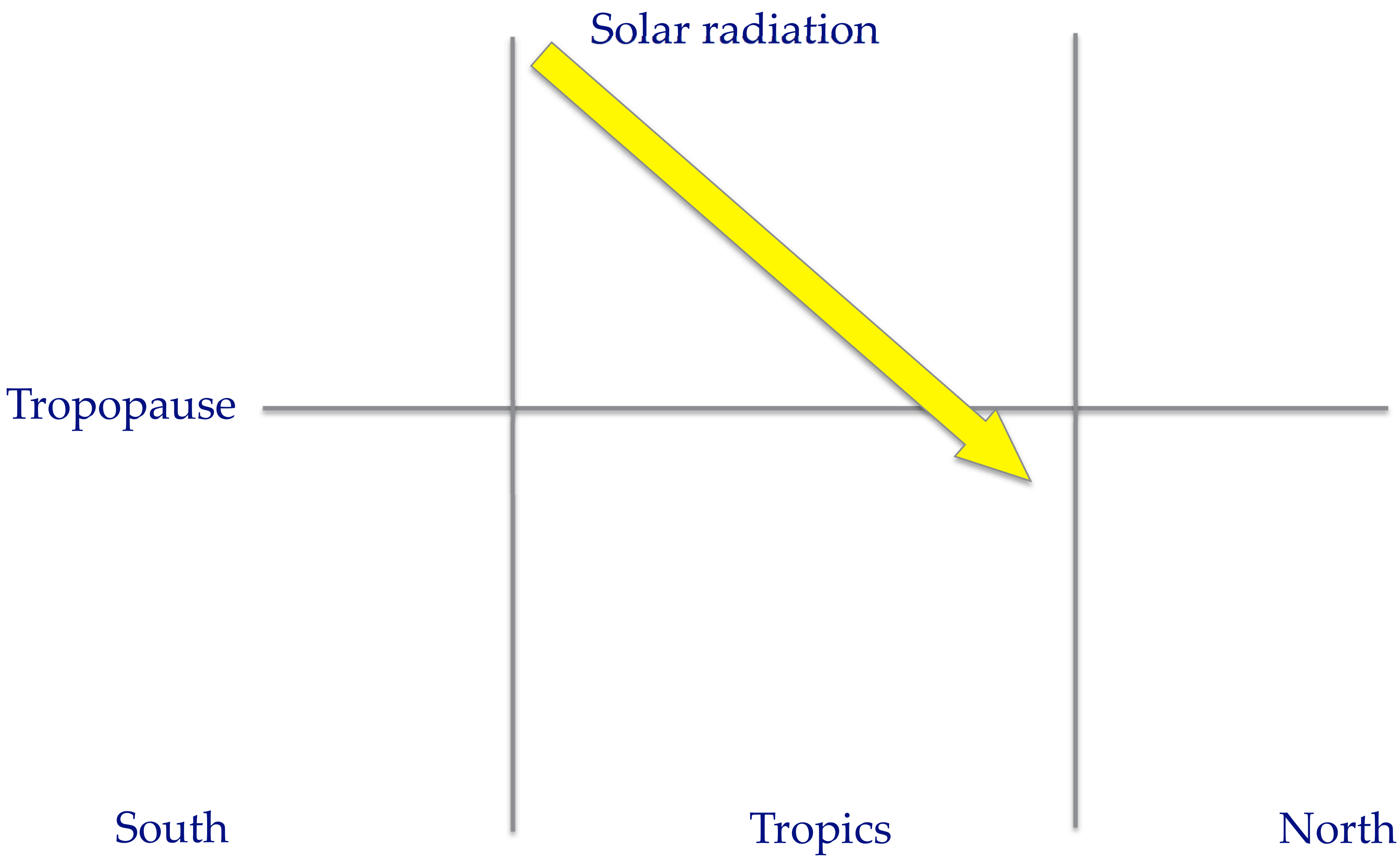
Introduction

→ **Positive NAO conditions observed during the two winters following the Pinatubo eruption in 1991…**

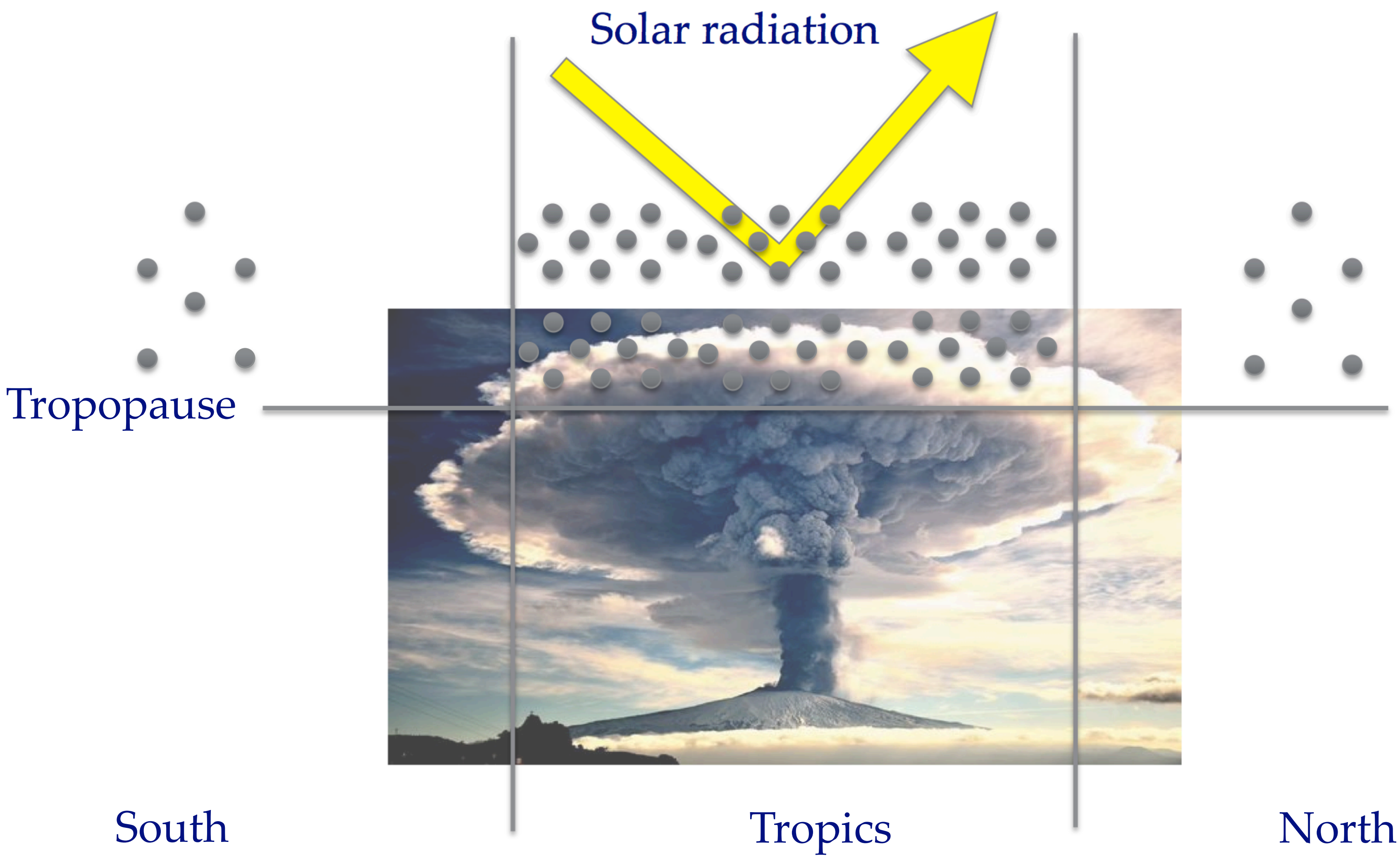
and

… the beginning of a passionate and unclosed debate!!!

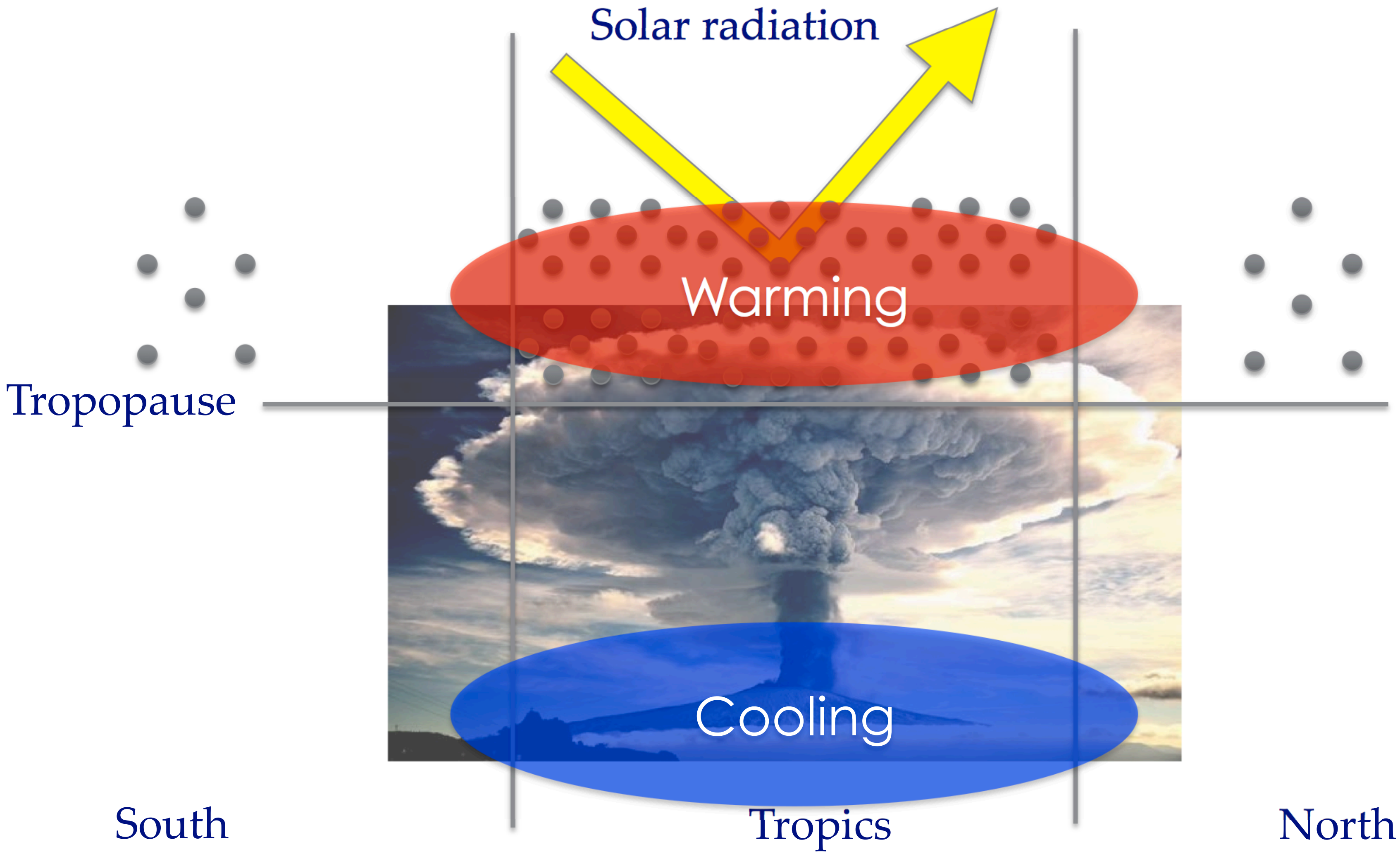
Mechanisms



Mechanisms

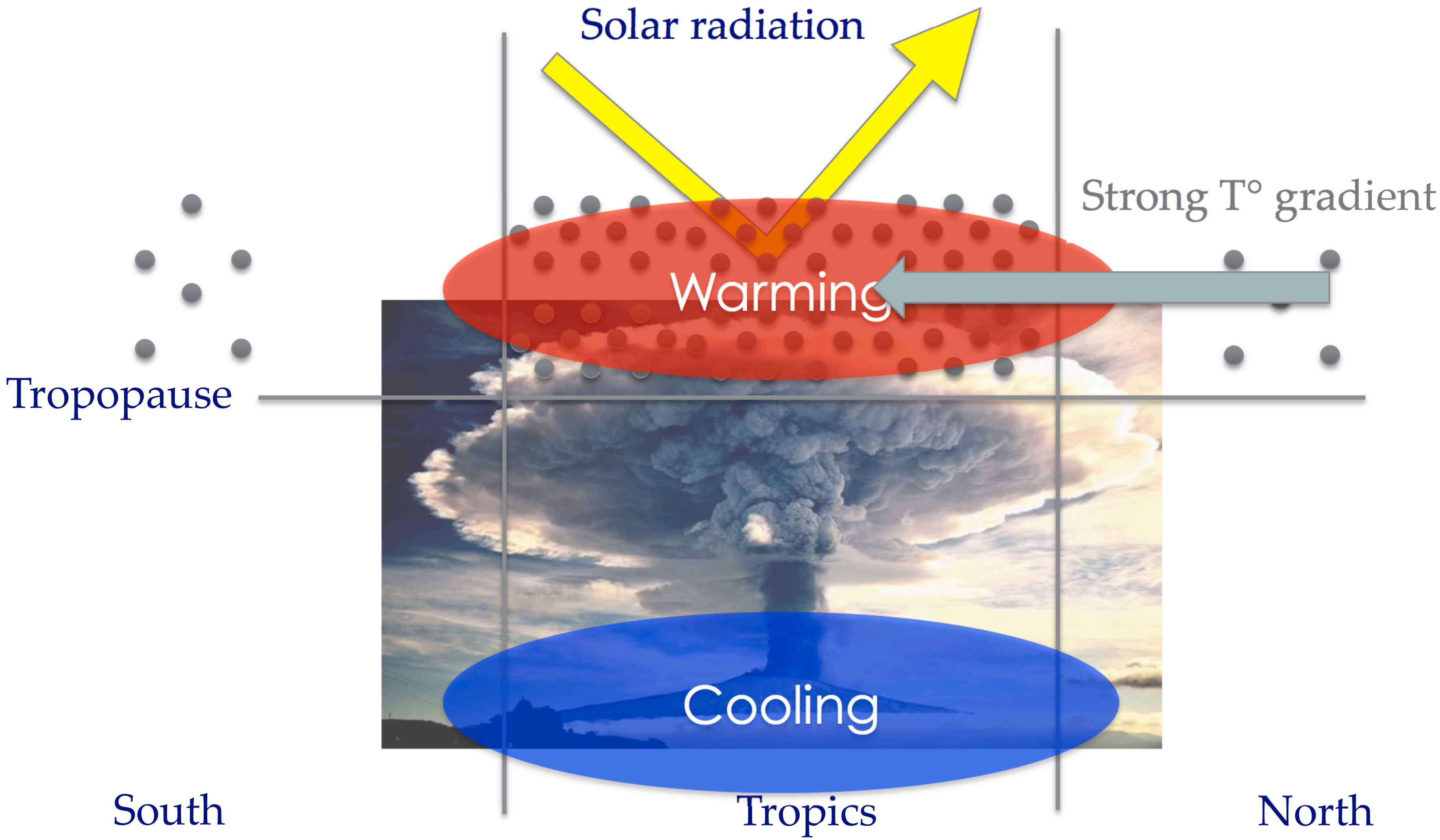


Mechanisms

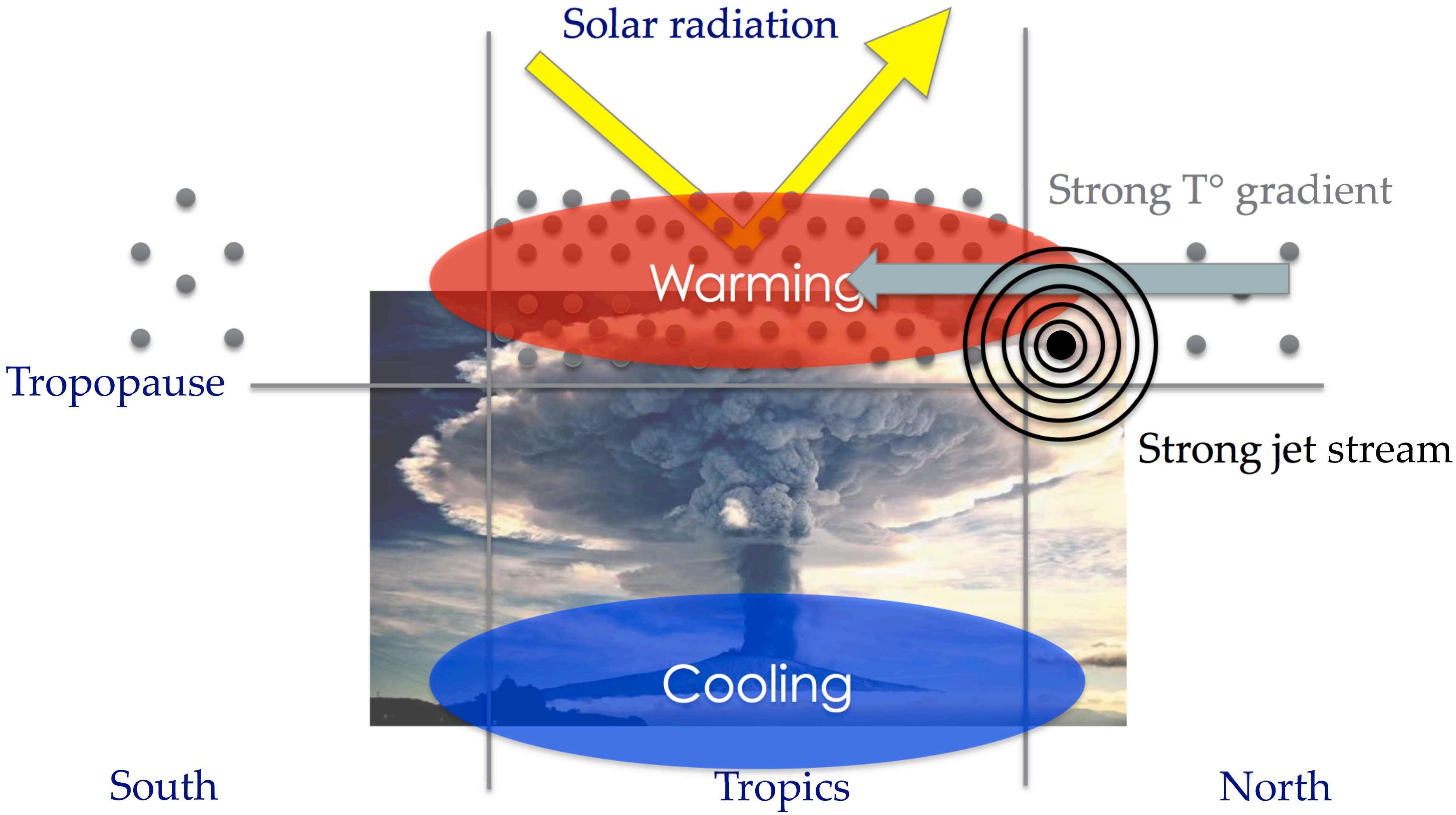


Solar radiation
Warming
Tropopause
Cooling
South
Tropics
North

Mechanisms

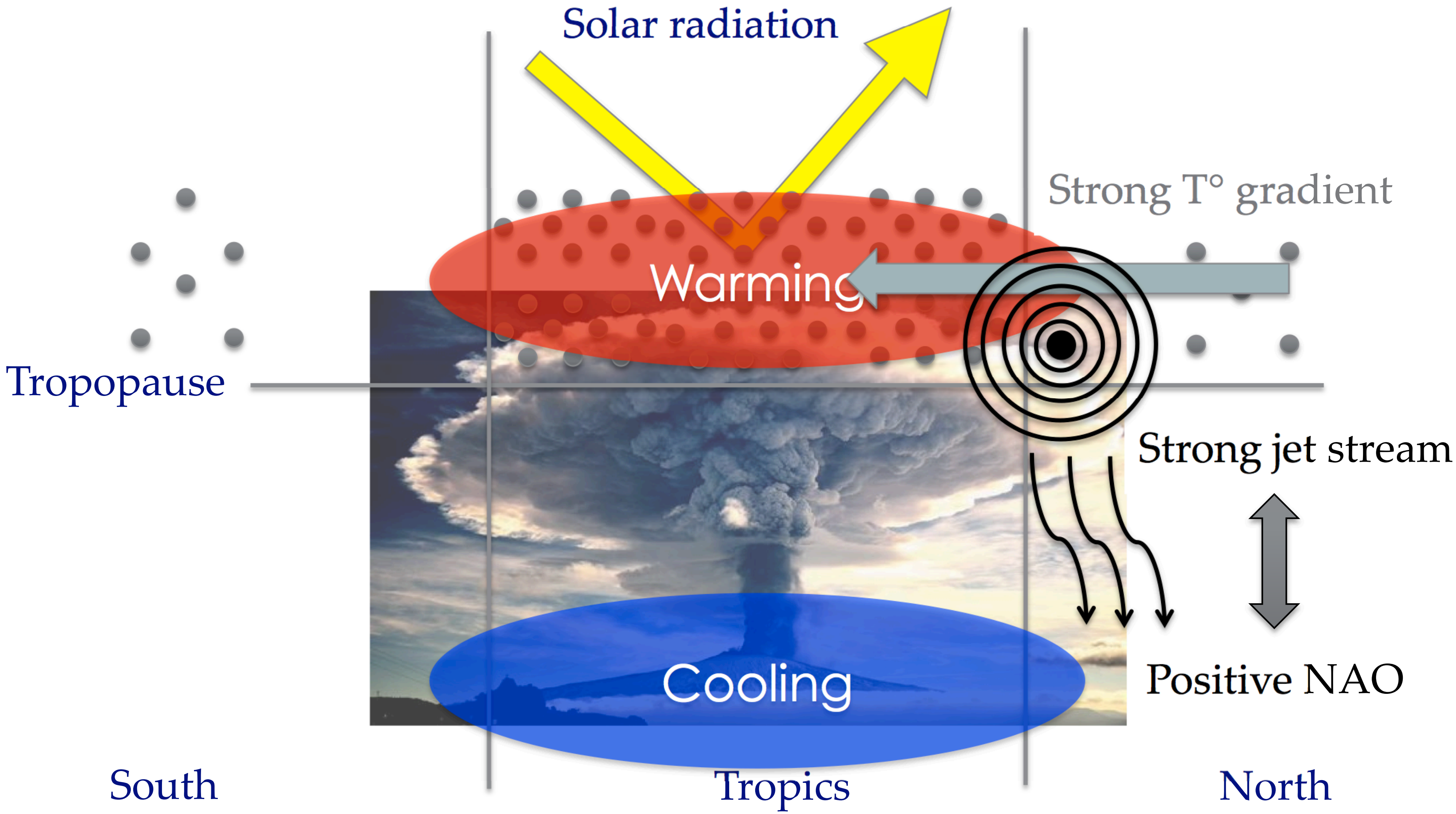

Solar radiation
Strong T° gradient
Warming
Tropopause
Cooling
South
Tropics
North

Mechanisms



Solar radiation
Strong T° gradient
Warming
Tropopause
Strong jet stream
Cooling
South
Tropics
North

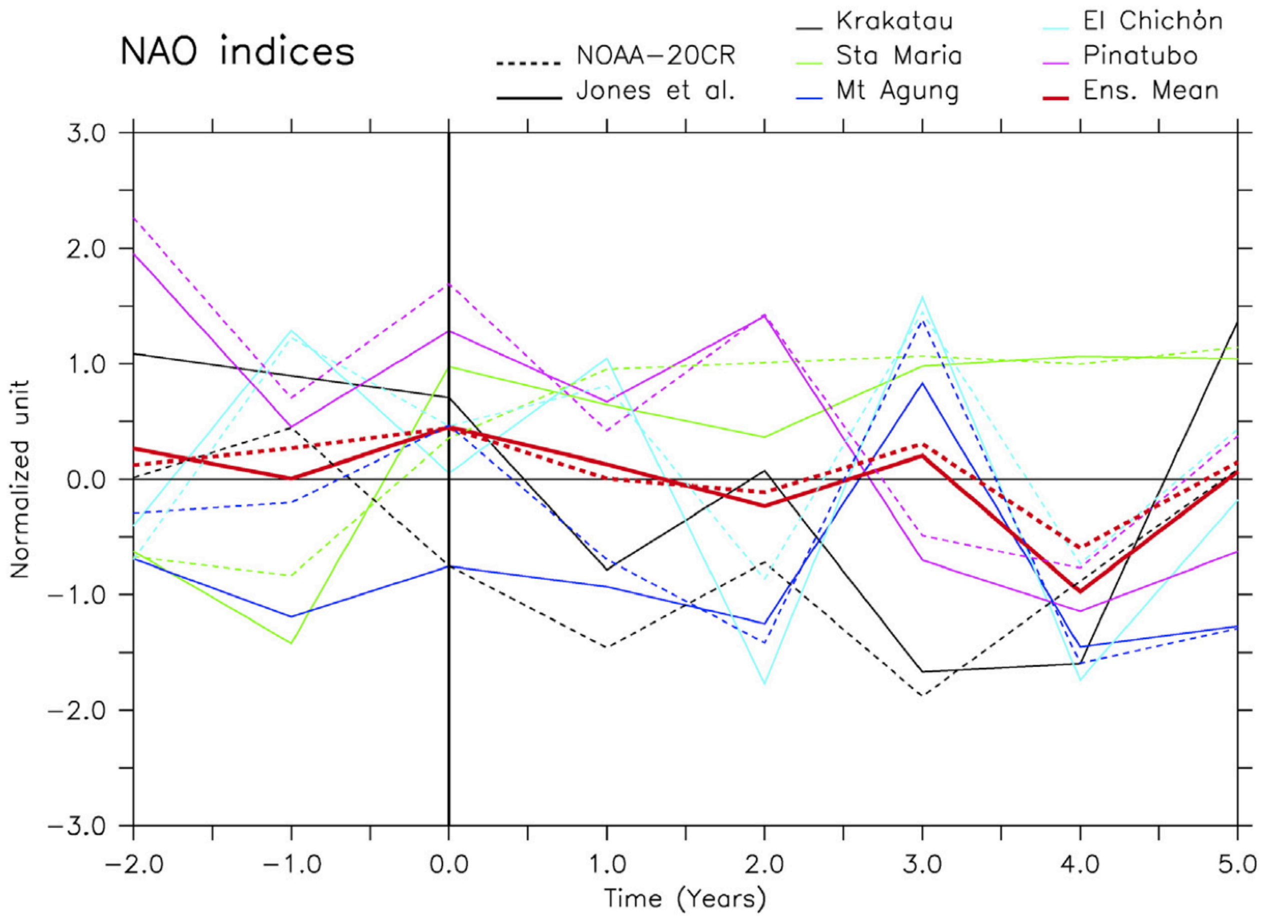
Mechanisms



Solar radiation
Strong T° gradient
Warming
Tropopause
Strong jet stream
Positive NAO
Cooling
South
Tropics
North

Observations

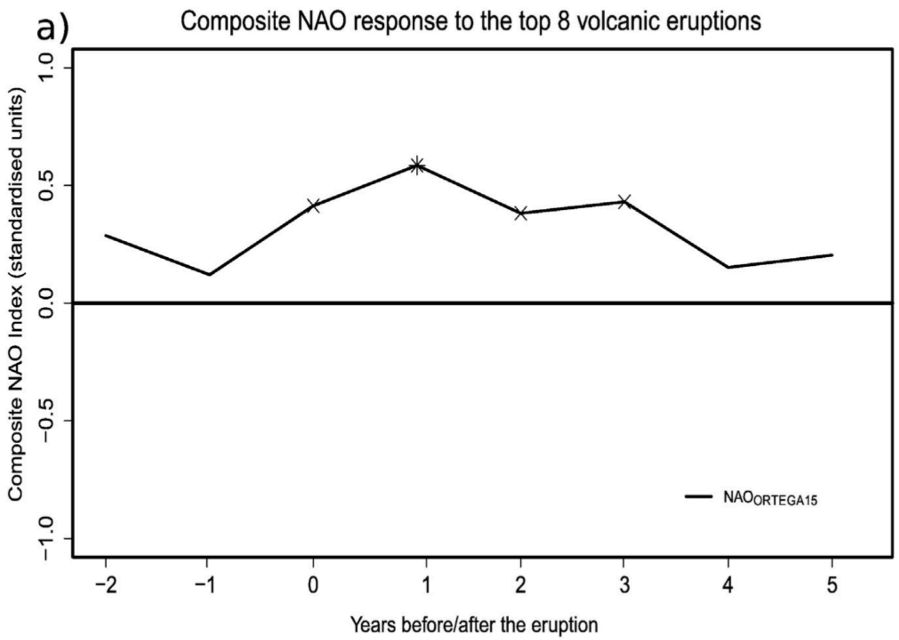
→ **No evidence for any winter NAO signal after the last five major eruptions!**



(Swingedouw et al., 2017)

Observations

→ **But positive NAO signal after the 8 major eruptions of the last 1000 years (very large eruptions, stronger than the Pinatubo)**

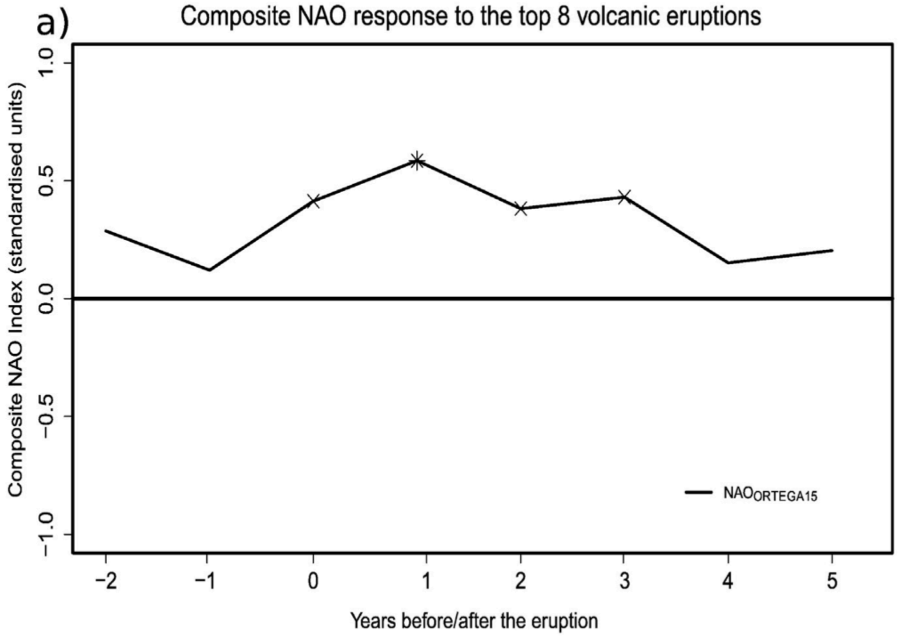


Observations

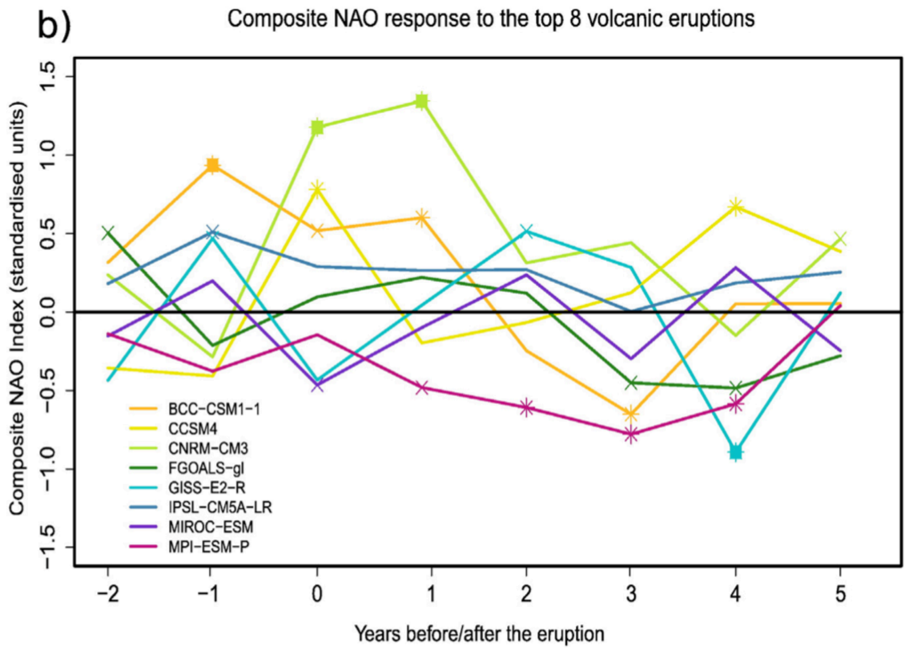
(Ortega et al., 2015; Swingedouw et al., 2017)

Observations

→ But positive NAO signal after the 8 major eruptions of the last 1000 years (very large eruptions, stronger than the Pinatubo)



Observations



Not reproduced by all the models!

(Ortega et al., 2015; Swingedouw et al., 2017)

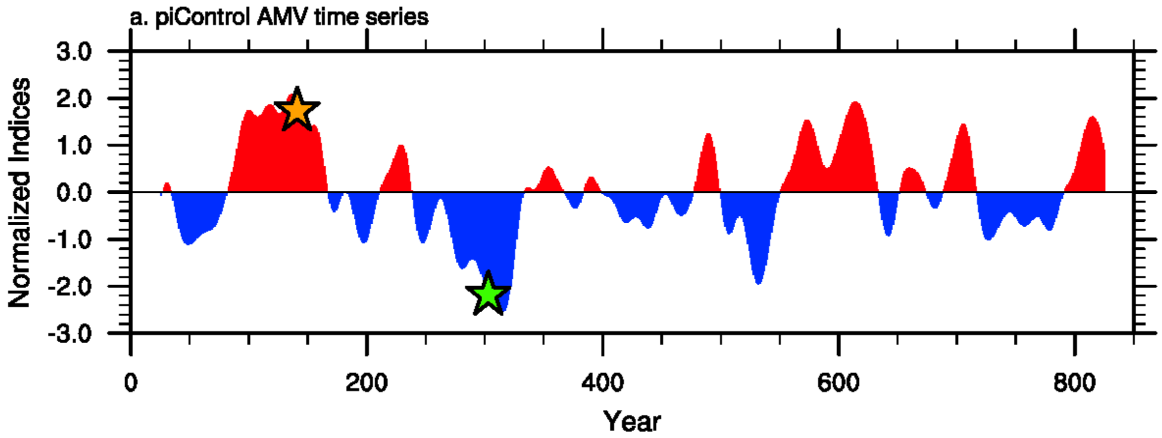
Model experiments

→ **Does the NAO response depend on the climate conditions in the Atlantic?**

→ **Can we detect this signal from the internal variability?**

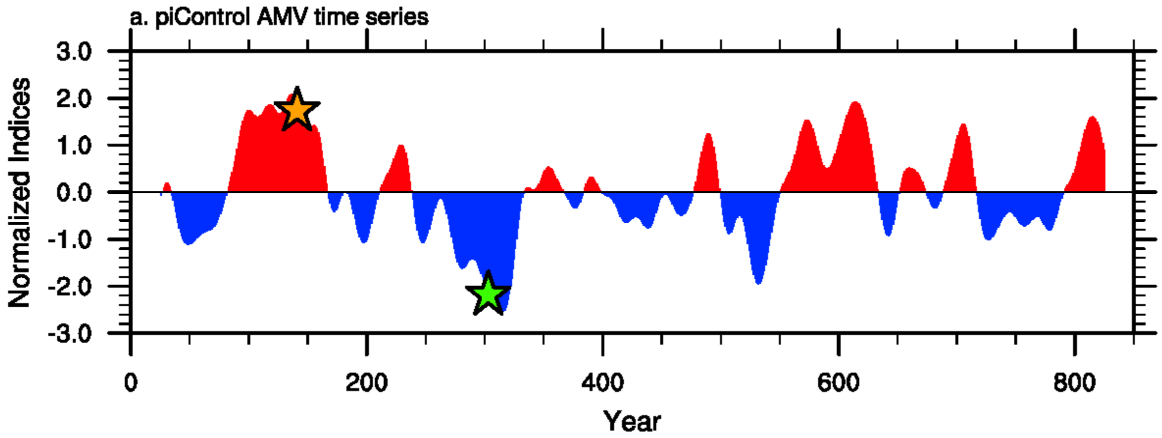
Model experiments

→ **850 years control experiment**

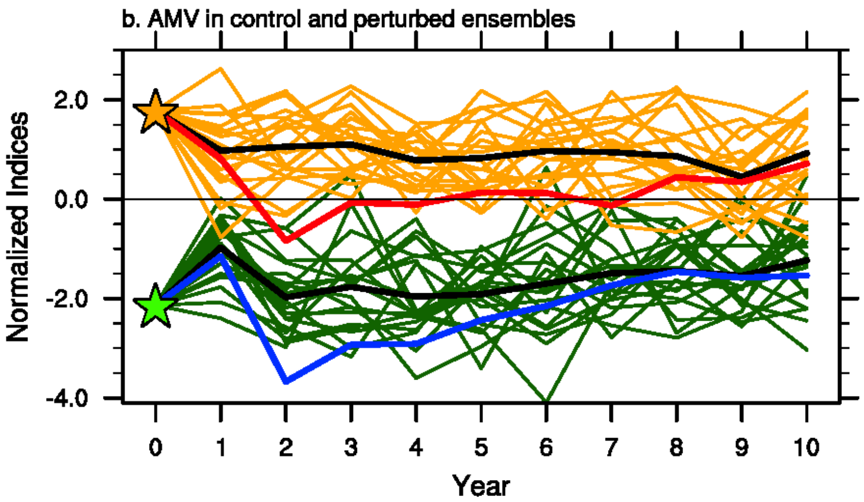


Model experiments

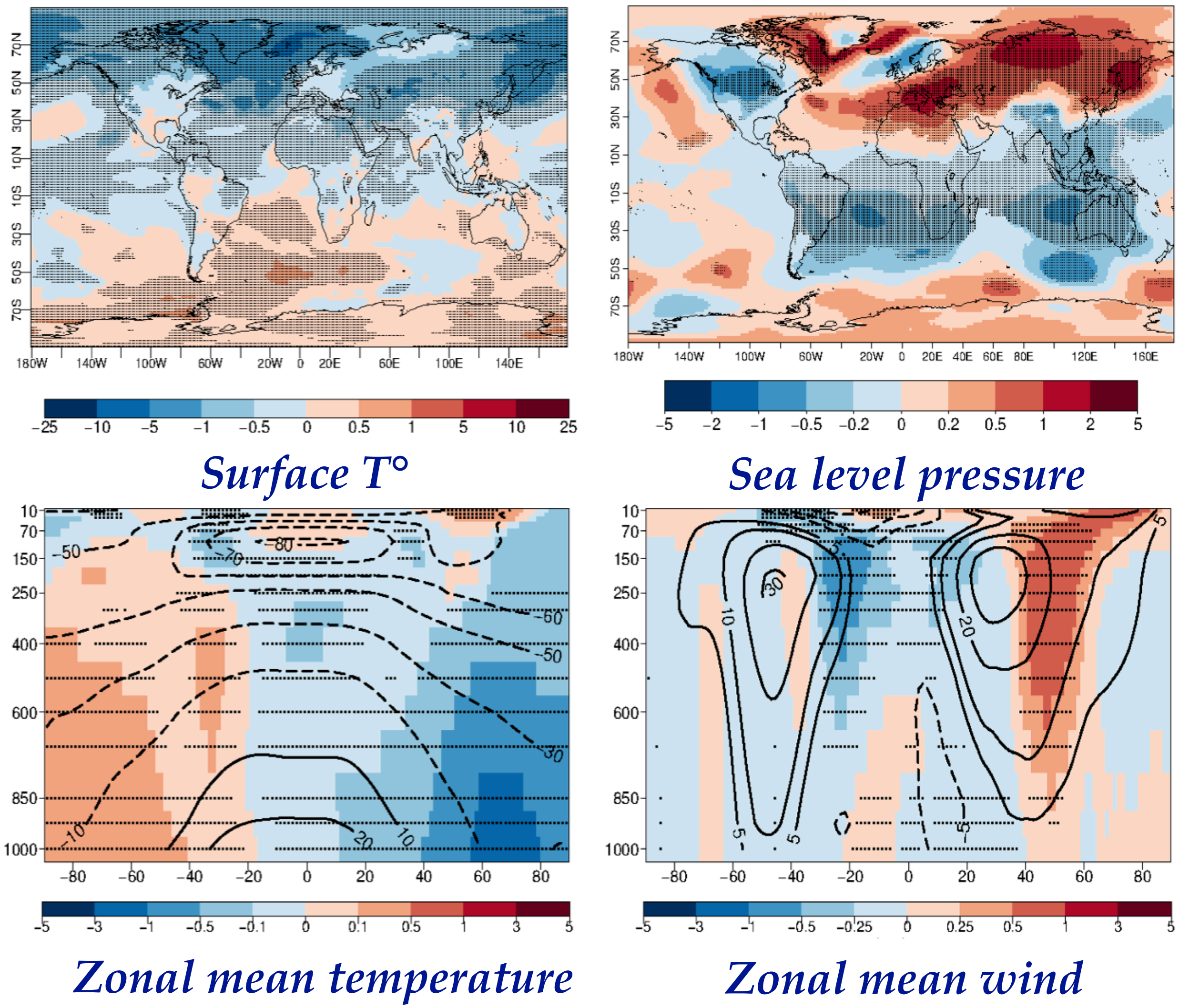
→ 850 years control experiment



→ Simulating a Pinatubo under warm/cold phases of the AMV



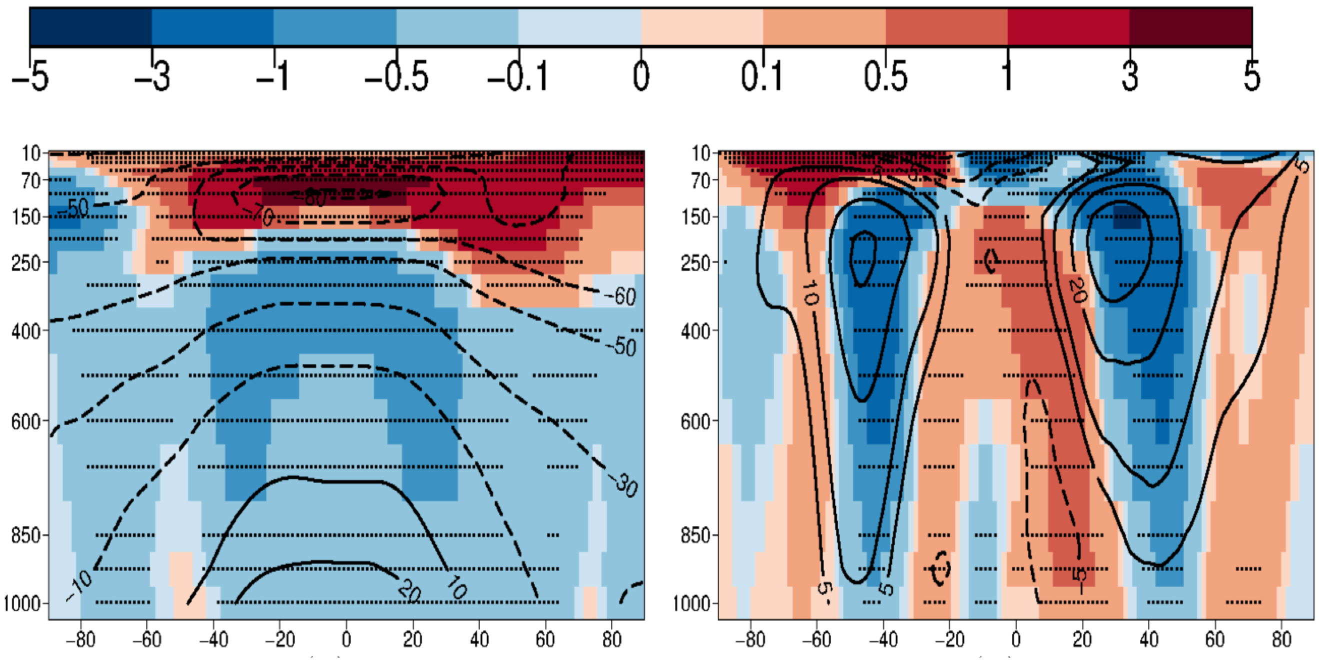
AMV- versus AMV+



Winter ensemble mean differences between simulations run under warm and cold AMO conditions (36 members)

Model experiments

First winter anomalies after a Pinatubo eruption, cold AMV case

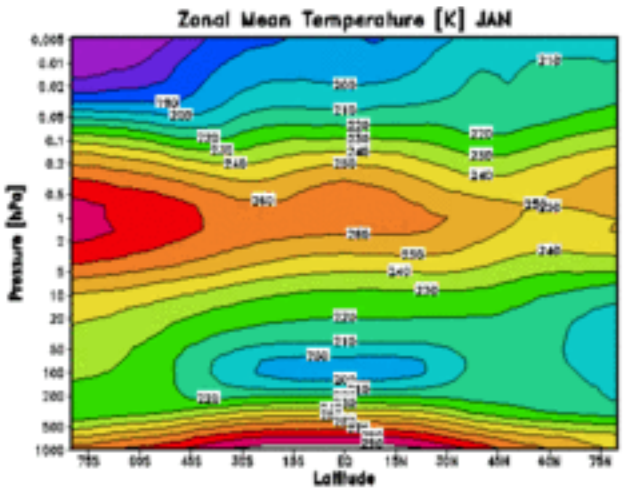


Temperature (°C) Zonal wind (m.s[-1])

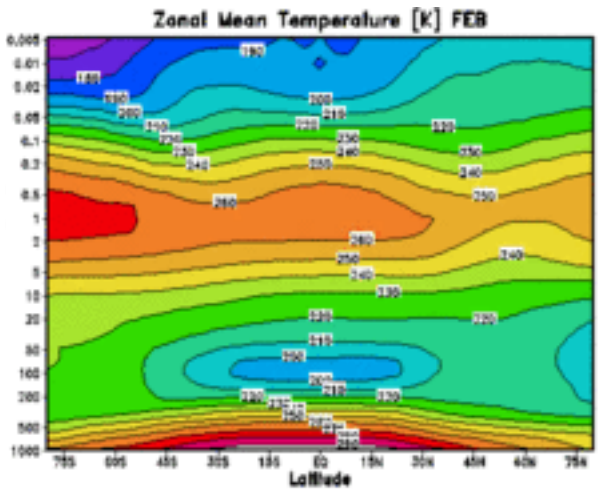
Climatology (contours) and anomalies (shading), from Ménégoz et al. (in rev.)

Stratospheric observations

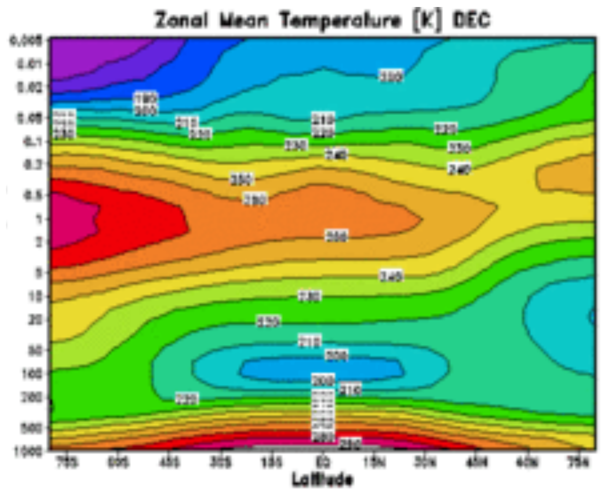
Climatology of the zonal mean of temperature:



January



February



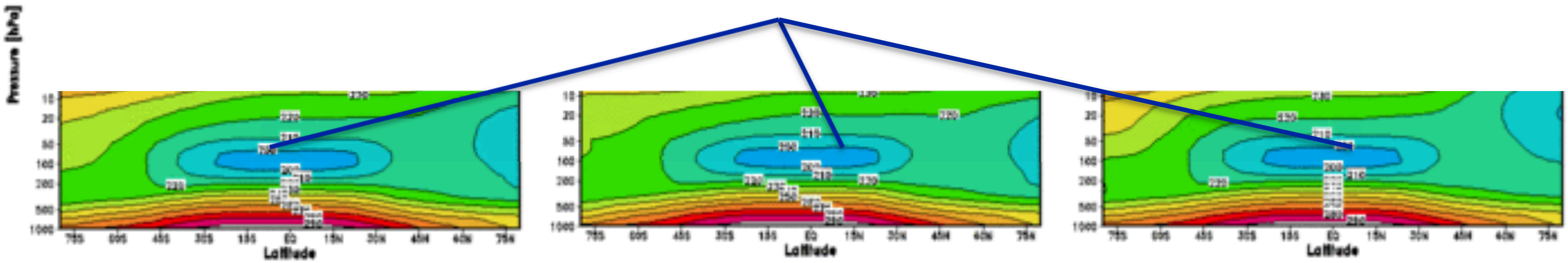
March

SPARC dataset (http://www.sparc-climate.org/)

Stratospheric observations

Climatology of the zonal mean of temperature:

At 100 hPa, the stratosphere is cooler in the Tropics than in the high latitudes

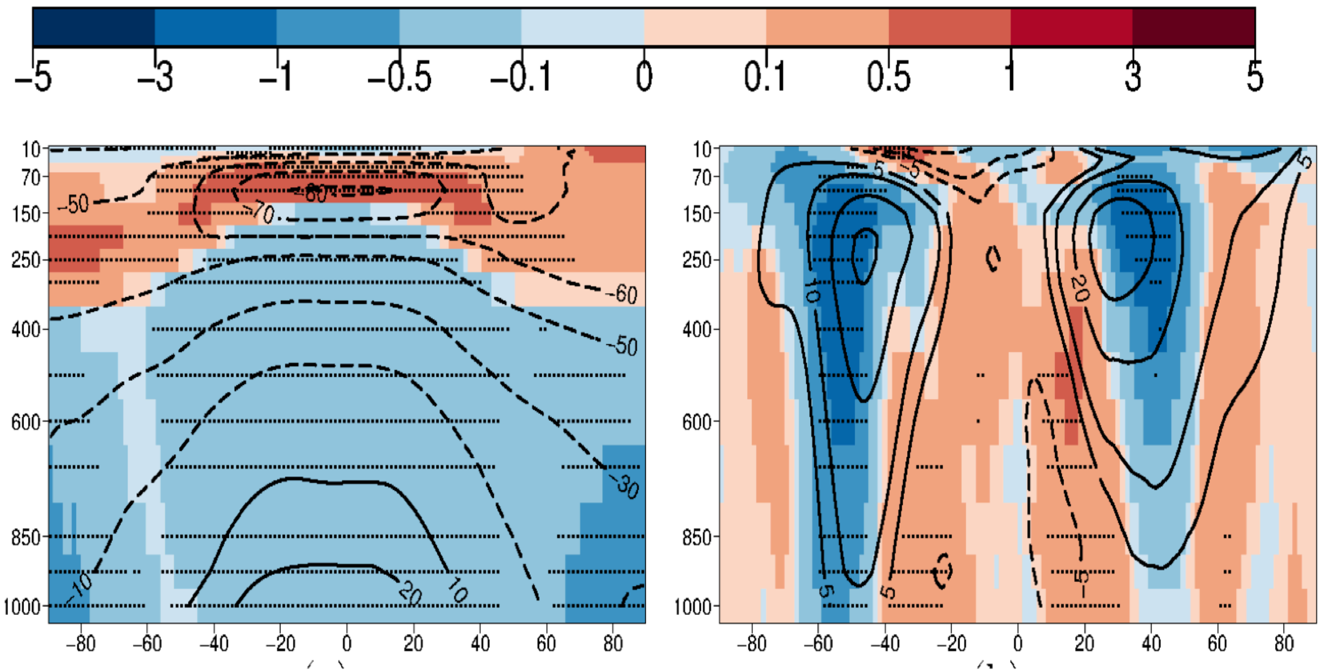


January February March

SPARC dataset (http://www.sparc-climate.org/)

Model experiments

Second winter anomalies after a Pinatubo eruption, cold AMV case

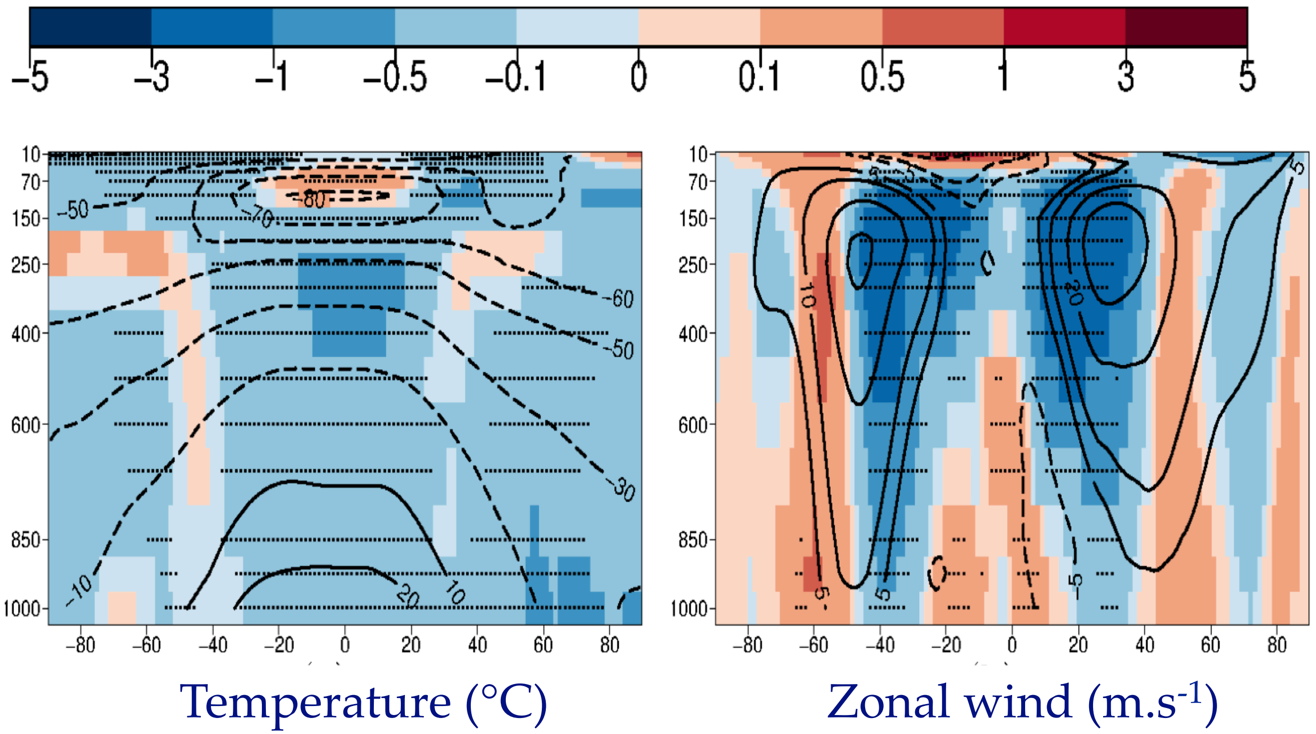


Temperature (°C) Zonal wind ($m.s^{-1}$)

Climatology (contours) and anomalies (shading), from Ménégoz et al. (in rev.)

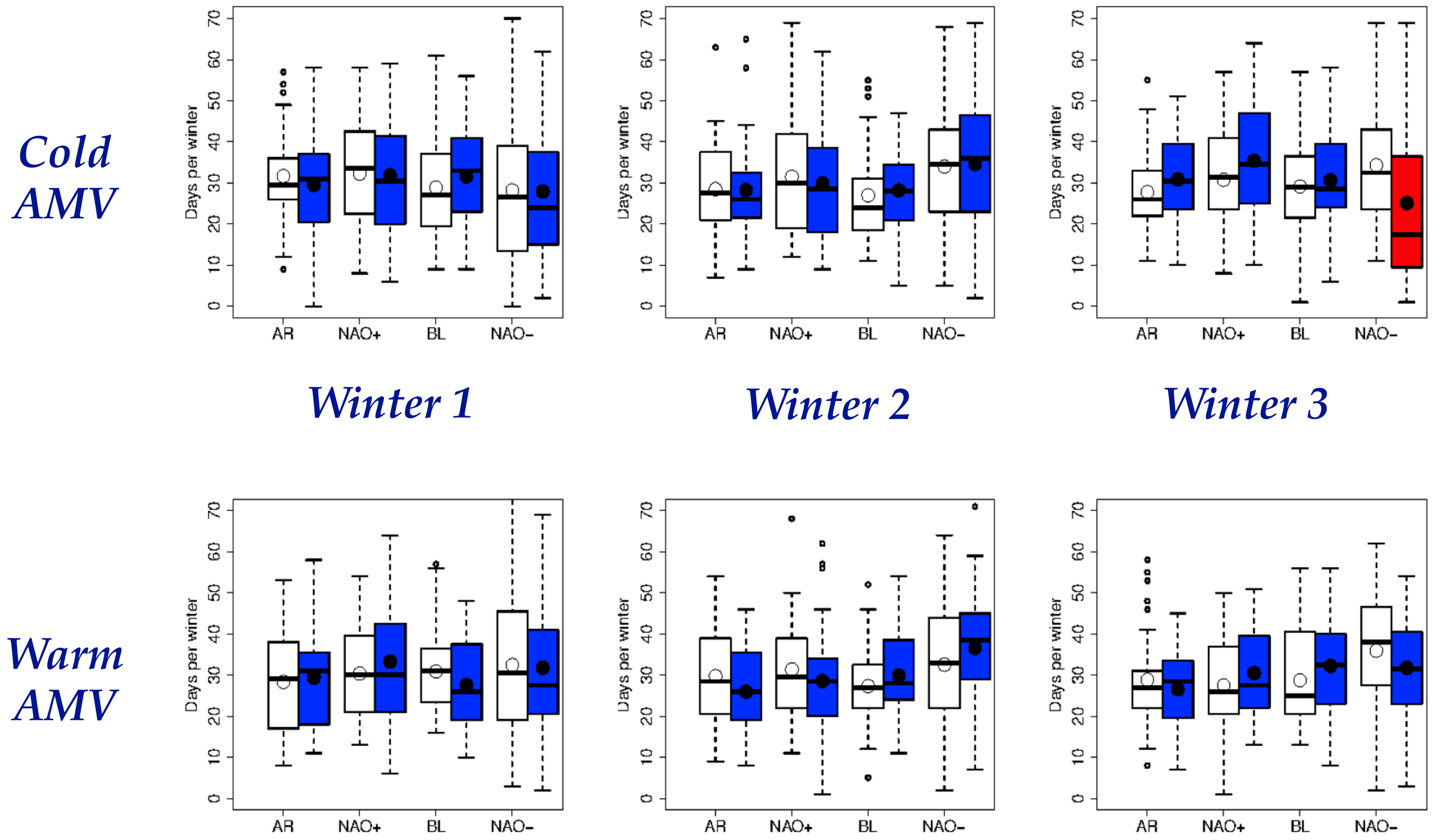
Model experiments

Third winter anomalies after a Pinatubo eruption, cold AMV case



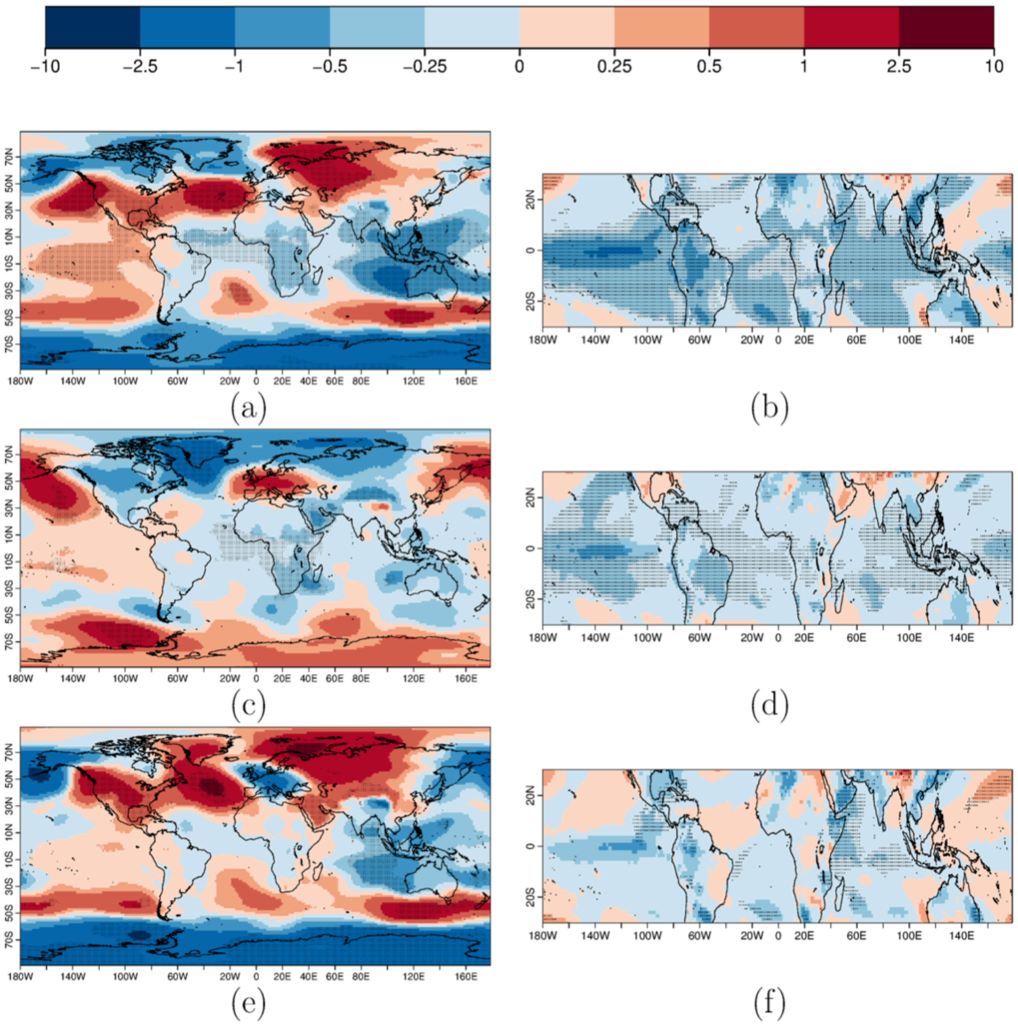
Climatology (contours) and anomalies (shading), from Ménégoz et al. (in rev.)

Weather regimes changes



Weather regime occurrences simulated the first winter after eruptions simulated under cold (up) and warm (bottom) AMV conditions.

Cold tropics under cold AMV



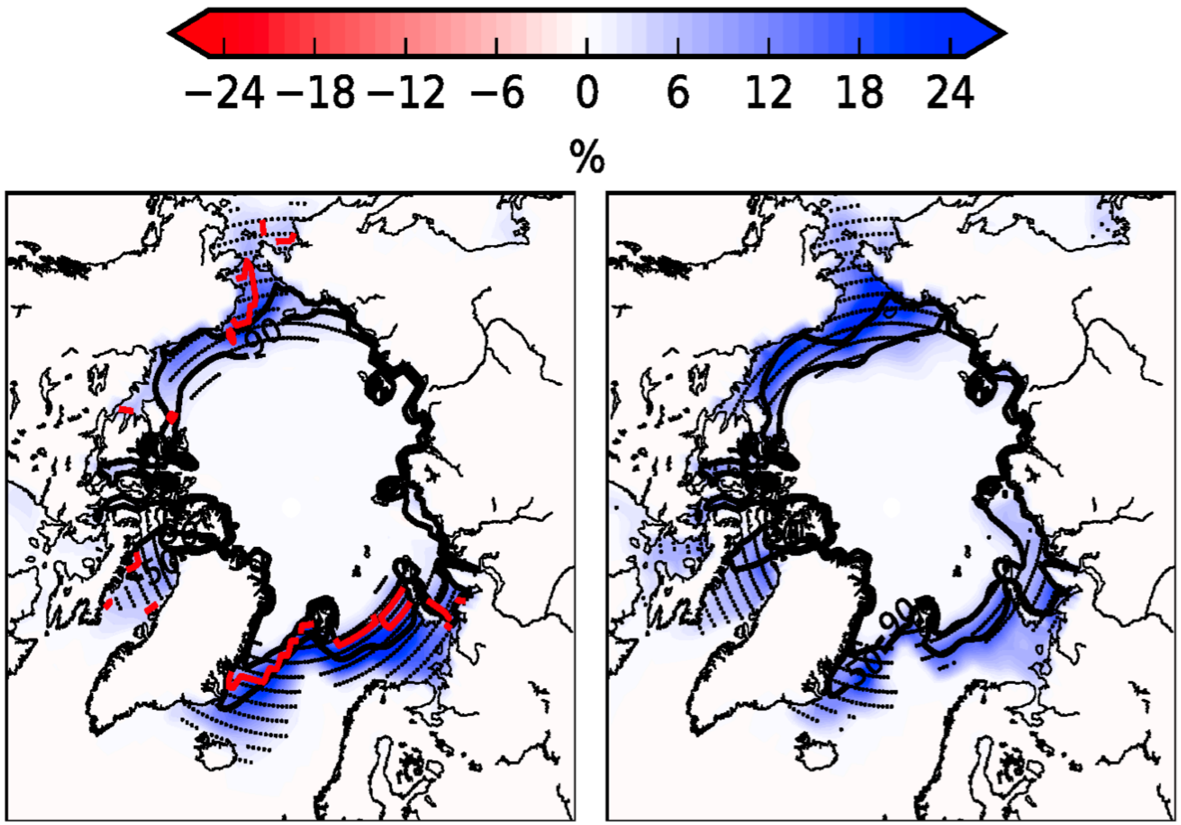
Cold AMV

Warm AMV

Cold – warm AMV

SLP anomaly *T° anomaly* *(3rd winter after the eruption)*

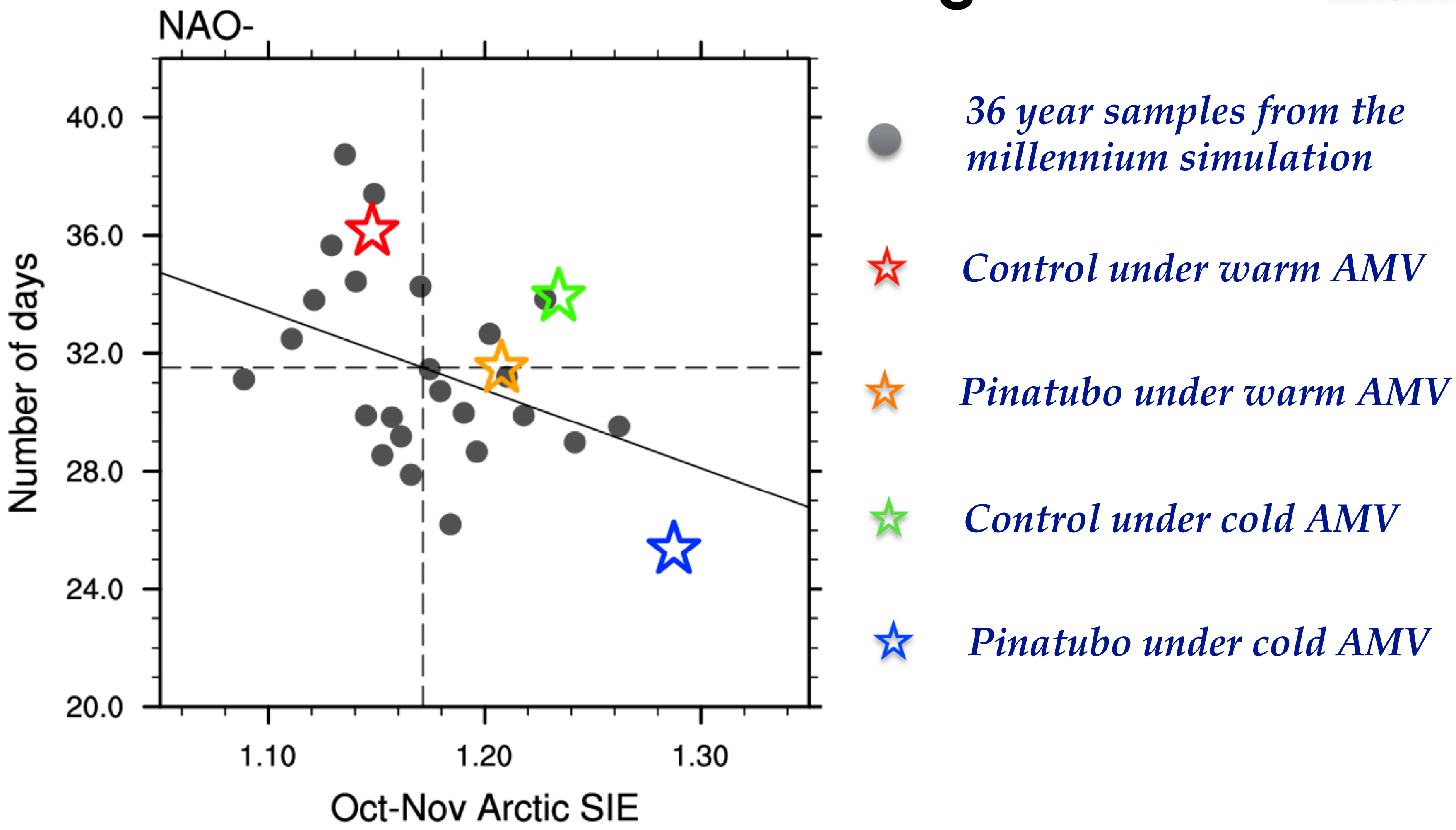
Sea-ice anomalies



Cold AMV *Warm AMV*

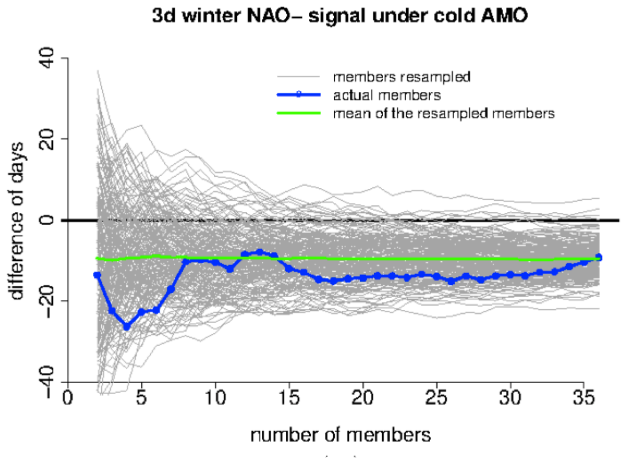
Sea-ice anomalies simulated the third autumn after a Pinatubo eruption. South of the red line, the response is stronger in the case of the cold AMV situation

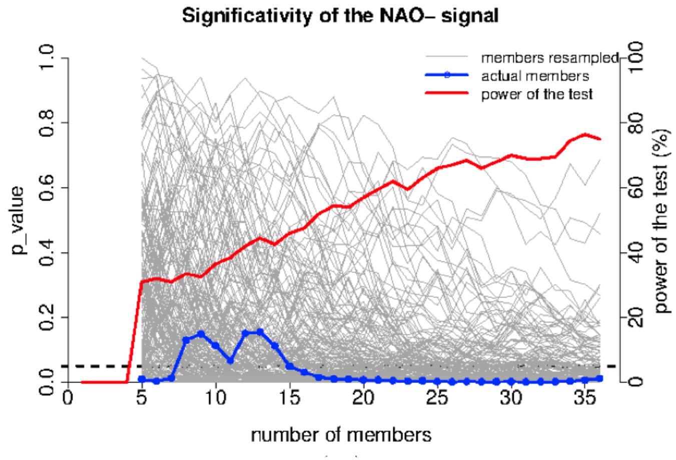
Autumn sea-ice versus winter NAO- regime



NAO- change the third winter

Cold AMO





Actual members

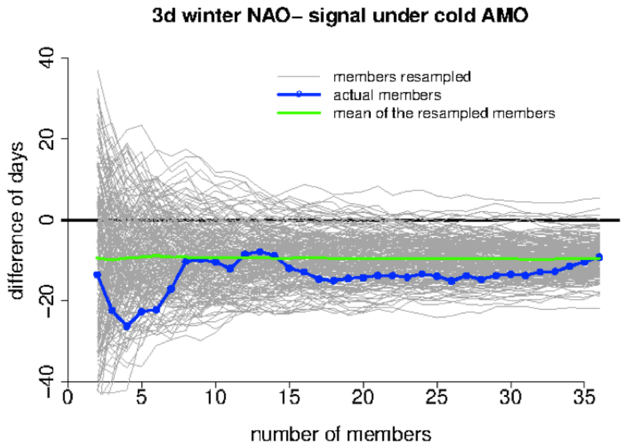
Members resampled

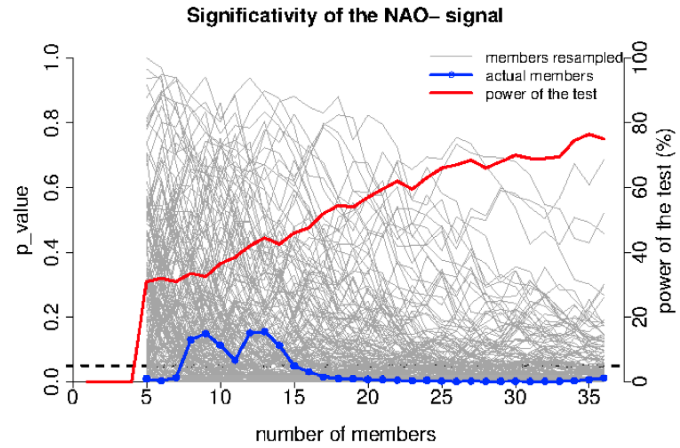
Volcanic signal / member mean (days)

P-value / power

NAO- change the third winter

Cold AMO





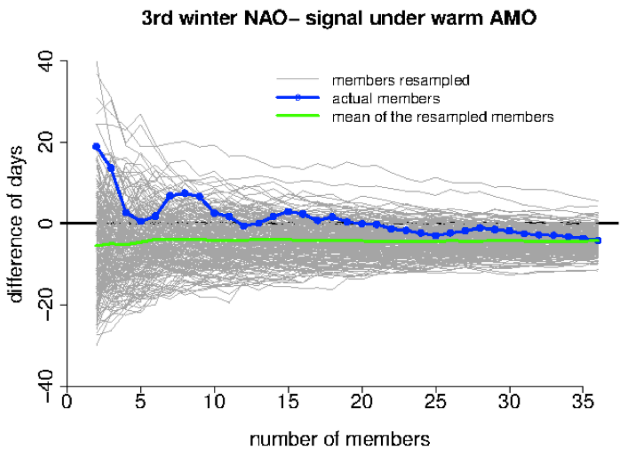
Actual members

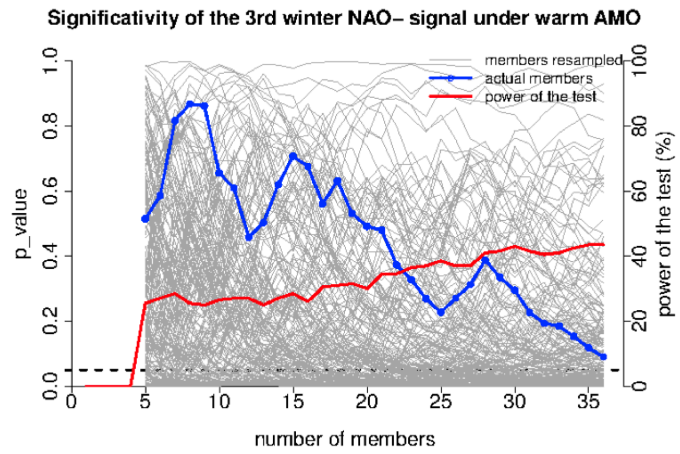
Members resampled

Volcanic signal / member mean (days)

P-value / power

Warm AMO



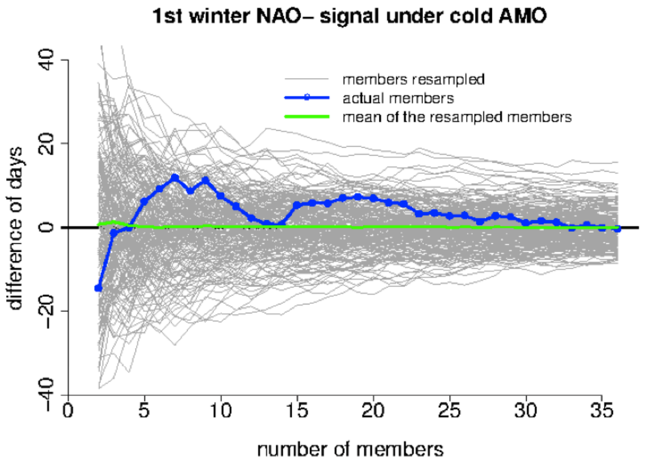


NAO- change the first winter

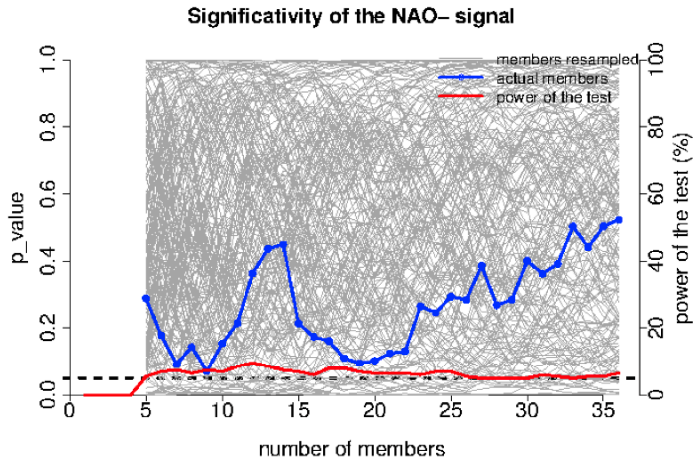
Cold AMO

Actual members

Members resampled



Volcanic signal / member mean (days)



P-value / power

SPECS

Conclusions

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→ **Observational evidence for a positive NAO signal persisting three winters after the largest eruptions of the last millennium.**

→ **Significant decrease of the NAO- occurrence the third winter after a Pinatubo eruption in the CNRM-CM5 model.**

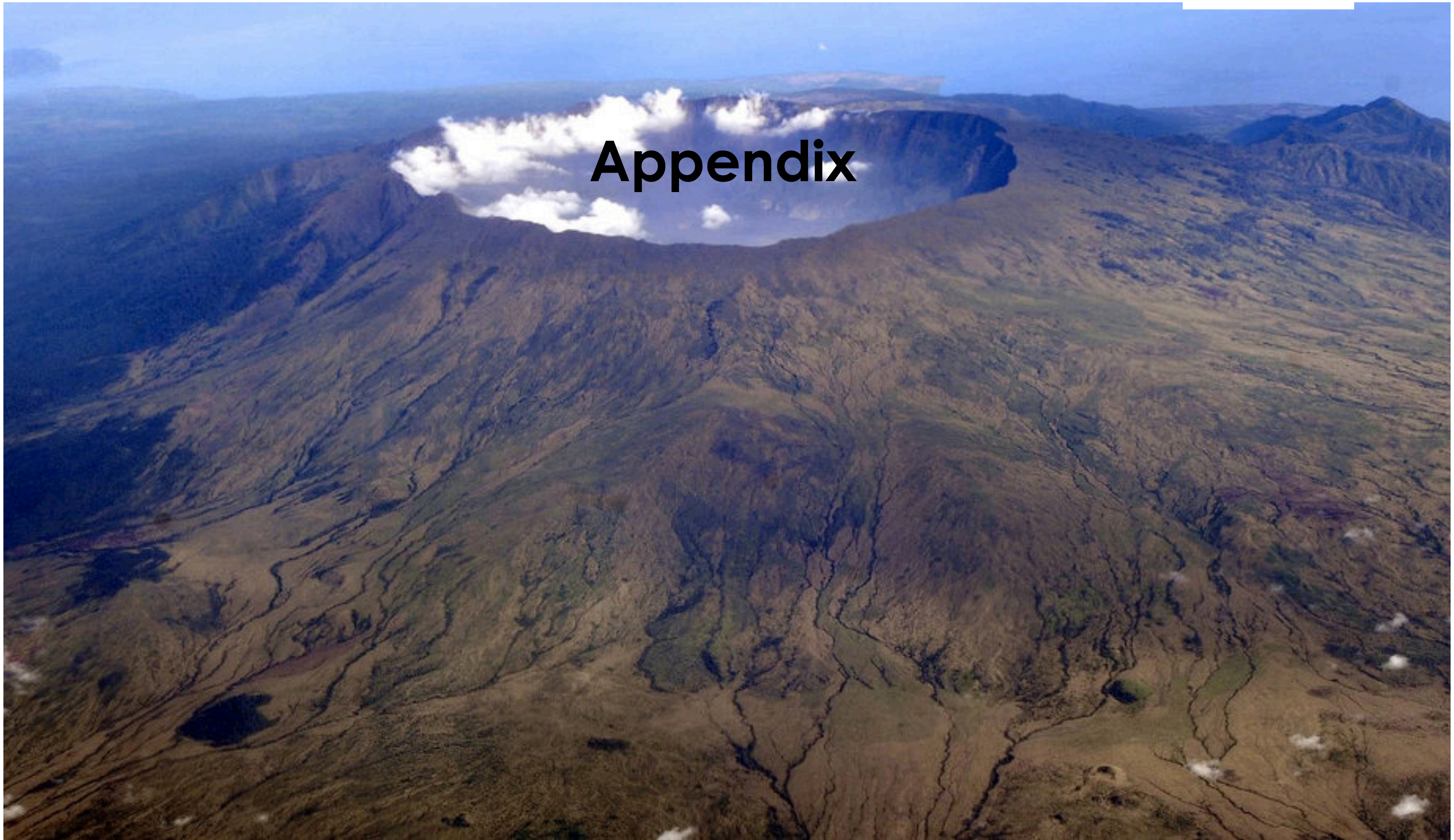
→ **This NAO- signal is related to surface feedbacks: cooler Tropics and sea-ice anomalies, especially pronounced under cold AMV conditions.**

→ **Detecting the NAO response to volcanic eruptions is challenging (low signal-noise ratio). Small ensemble experiments can give misleading results!**

- Swingedouw, D., Mignot, J., Ortega, P., Khodri, M., Ménégoz, M., Cassou, C., Hanquiez, V., 2017, Impact of explosive volcanic eruptions on the main climate variability modes, *Global and Planetary Change, Vol. 150, P. 24–45.*
- Ménégoz, M., Cassou, C., Swingedouw, D., Bretonnière, P.-A., Doblas-Reyes, F., Modulation of the climate response to a volcanic eruption by the Atlantic Multidecadal Variability, in revision for Climate Dynamics.

Thank you

Appendix

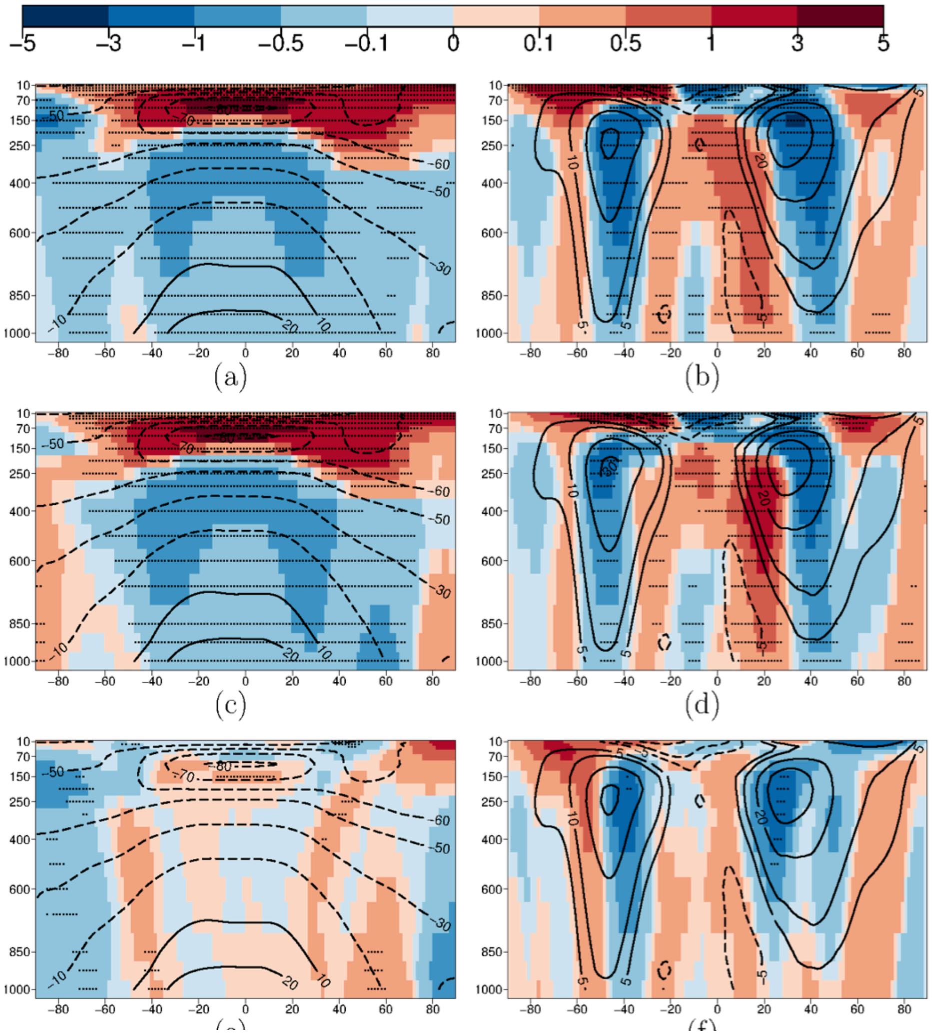


Volcanic signal – first winter

Cold AMO

Warm AMO

Cold – Warm



Temperature *Wind*

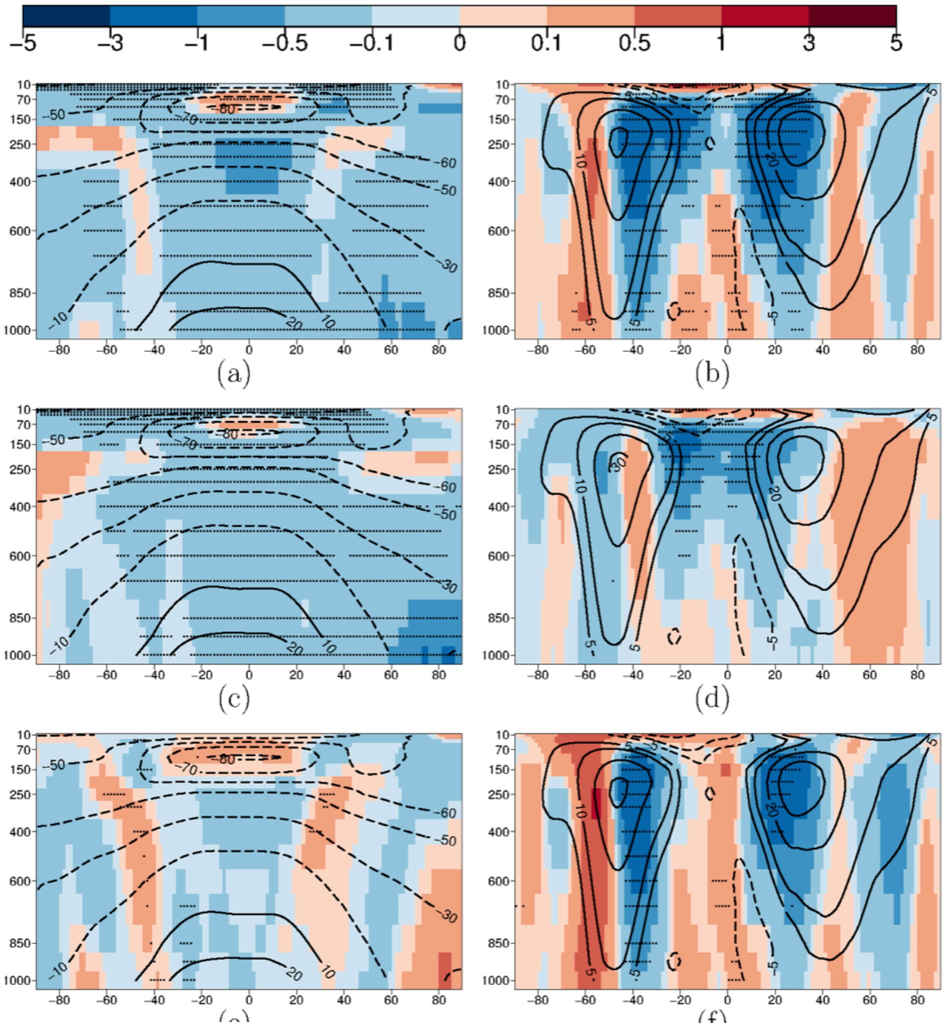
Zonal mean anomalies simulated the first winter after a volcanic eruption of temperature (°C, left) and wind (m.s-1, right)

Volcanic signal – third winter

Cold AMO

Warm AMO

Cold – Warm

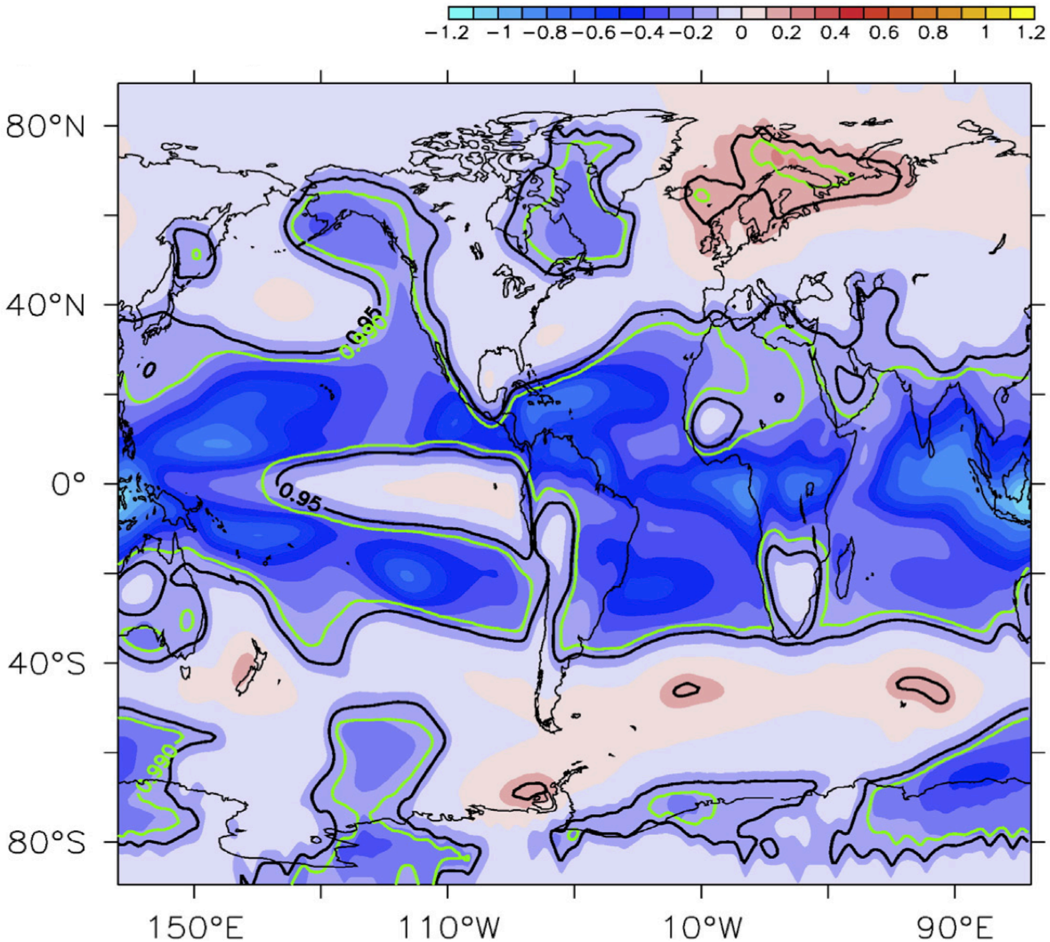


Temperature *Wind*

Zonal mean anomalies simulated the third winter after a volcanic eruption of temperature (°C, left) and wind (m.s-1, right)

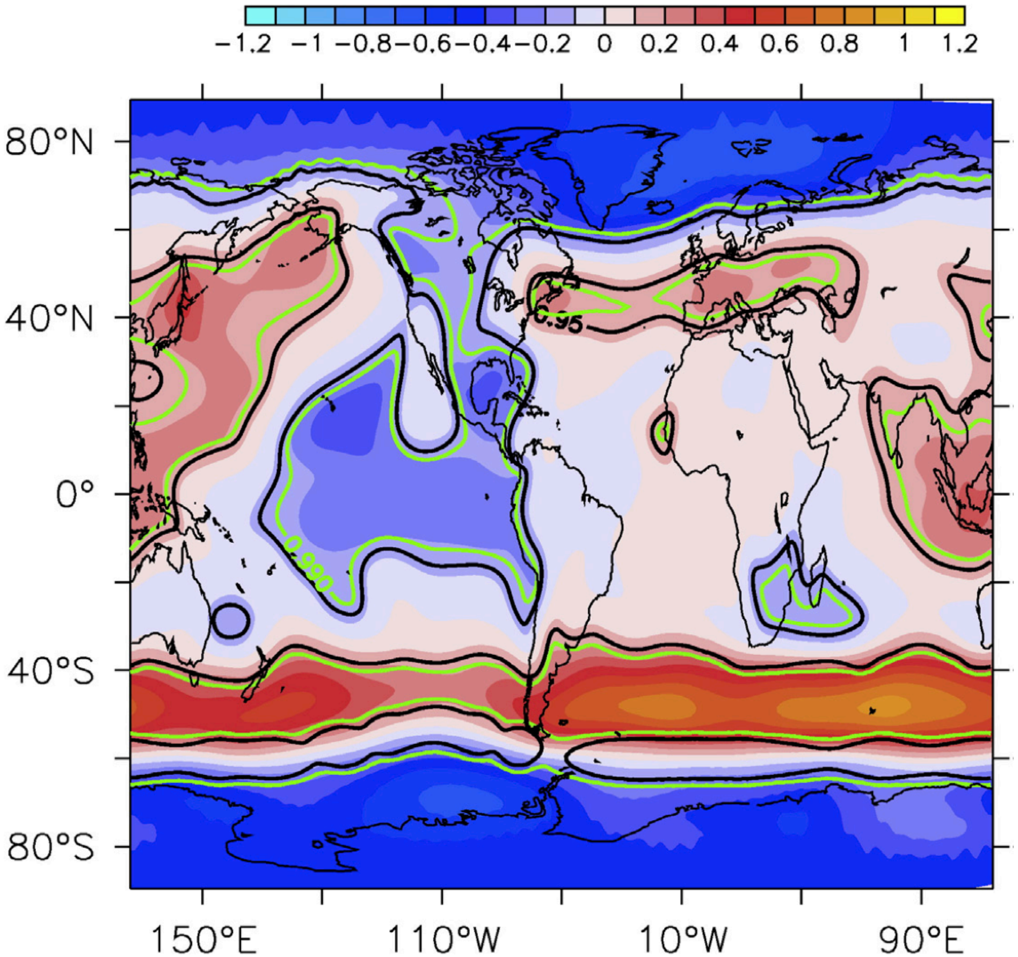
Introduction

→ **Regional variations of the cooling: dynamical response?**



Composite of two-meter temperature modelled with CNRM-CM3 for the 19 eruptions larger or equal to the Pinatubo over the last millennium, in terms of the duration of the aerosol imprint in the atmosphere. (Swingedouw et al., 2017)

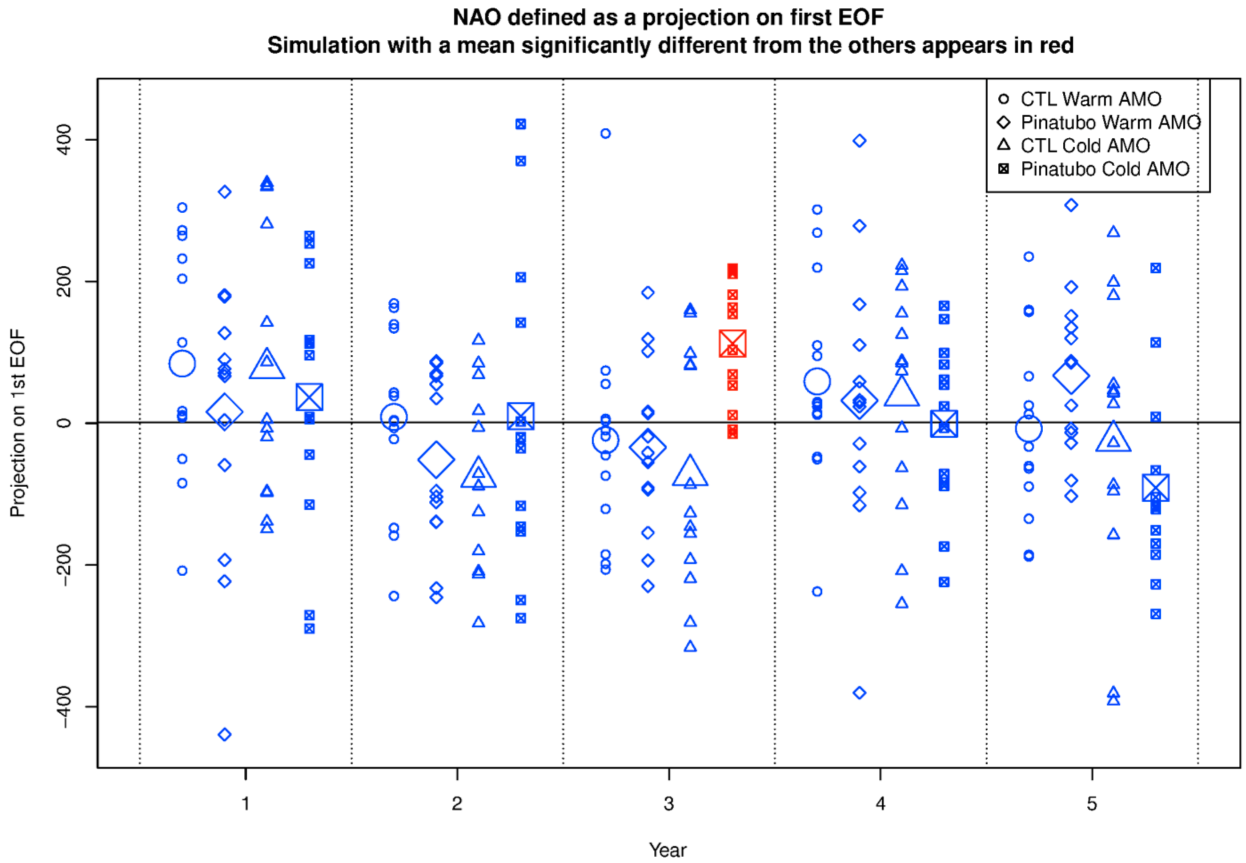
→ **Regional variations of the cooling: dynamical response?**



Composite of sea-level pressure modelled with CNRM-CM3 for the 19 eruptions larger or equal to the Pinatubo over the last millennium, in terms of the duration of the aerosol imprint in the atmosphere. (Swingedouw et al., 2017)

NAO and AMV

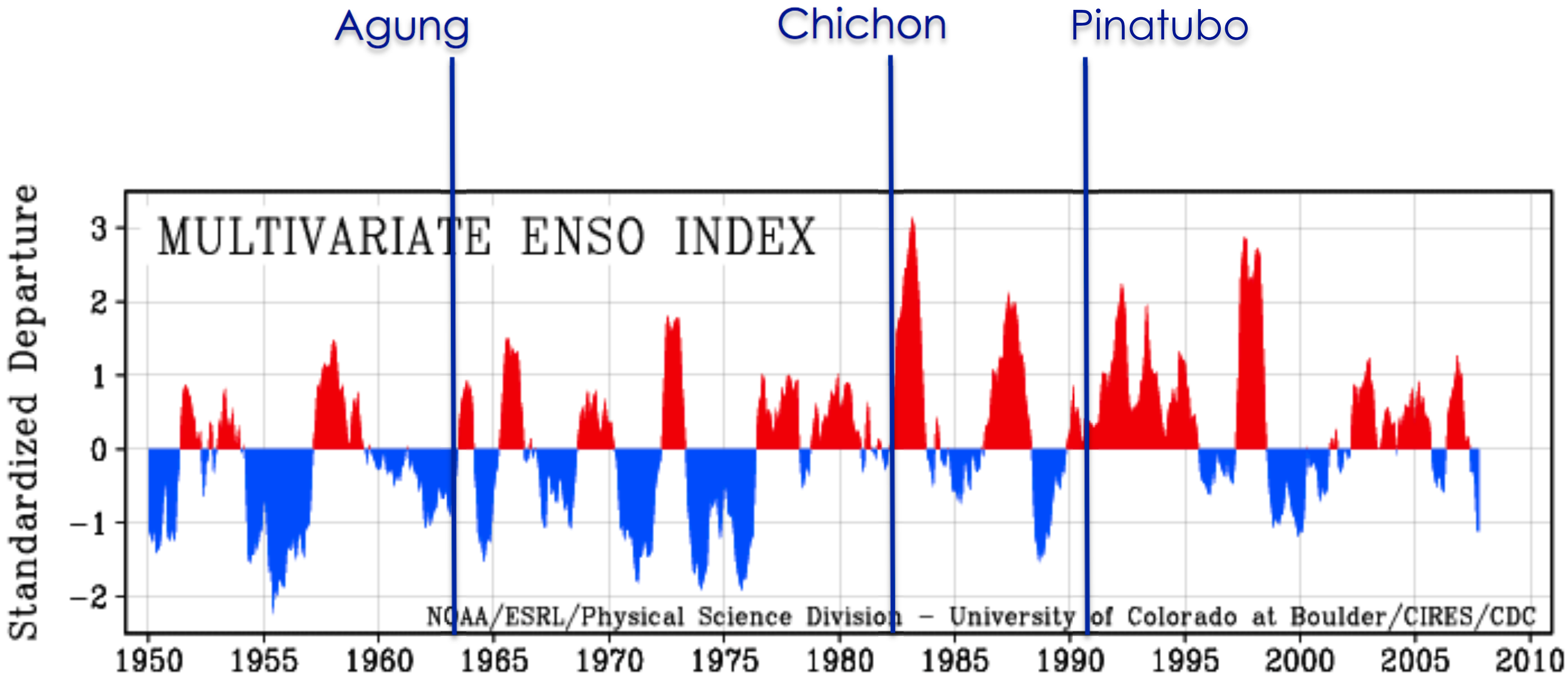
→ Simulating a Pinatubo under warm/cold phases of the AMV (Perfect model approach with the CNRM-CM5 model)

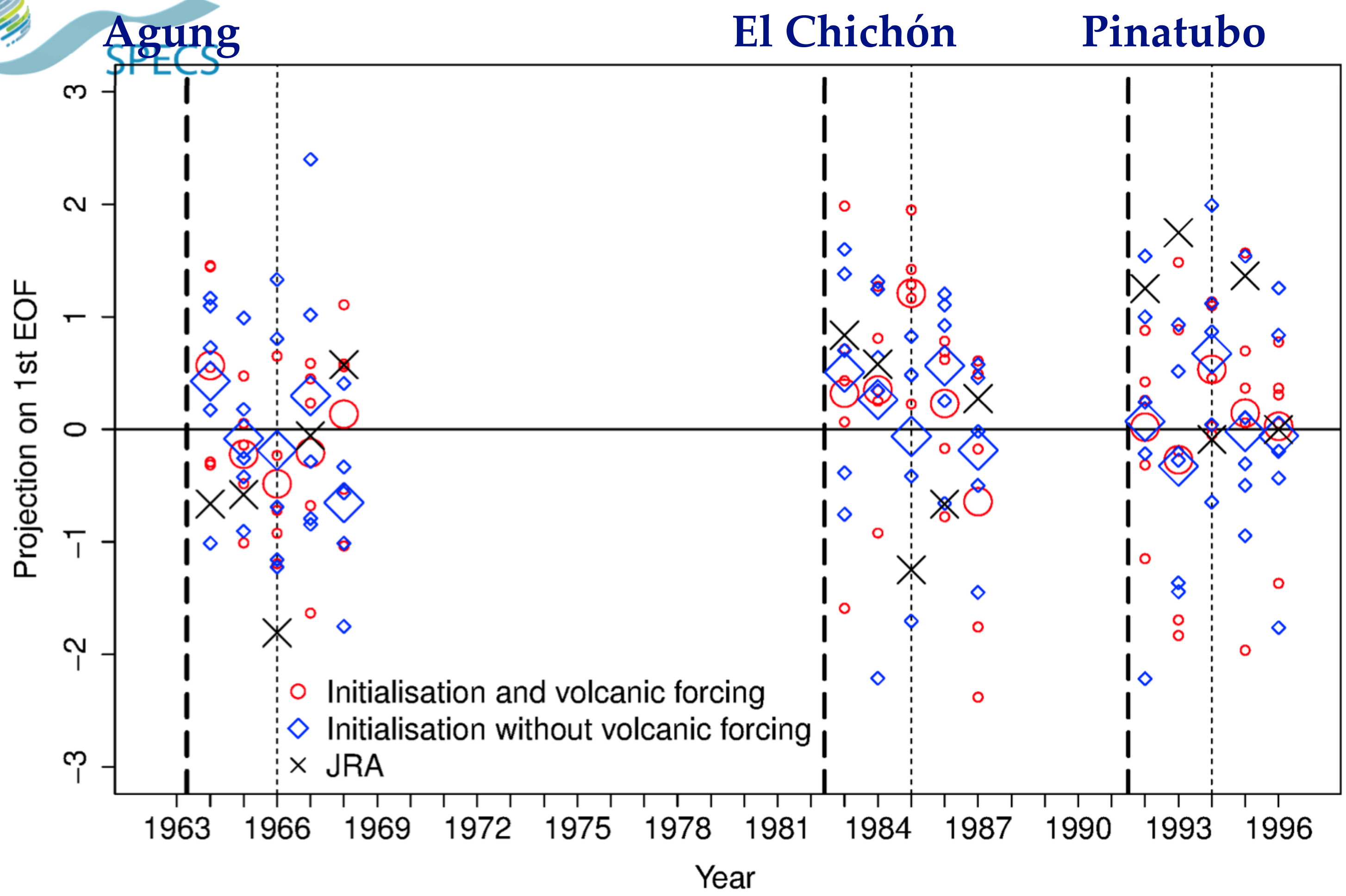


Significant NAO+ signal the third winter after a Pinatubo eruption under a cold AMV

Climate response to volcanoes

→ **Mixing between ENSO and volcanoes signals !**

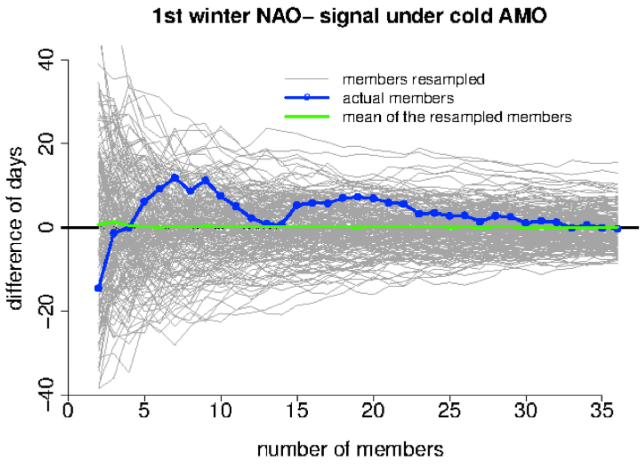


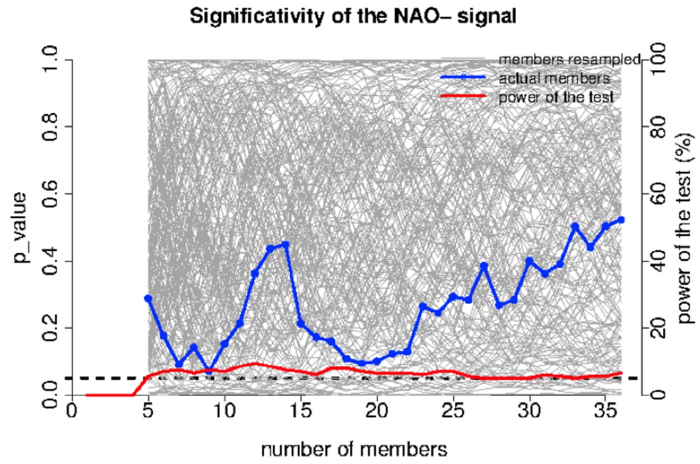


EC-Earth forecasts (colour) and observations (black) of the North Atlantic Oscillation (NAO) index after the last major volcanic eruptions

NAO- change the first winter

Cold AMO





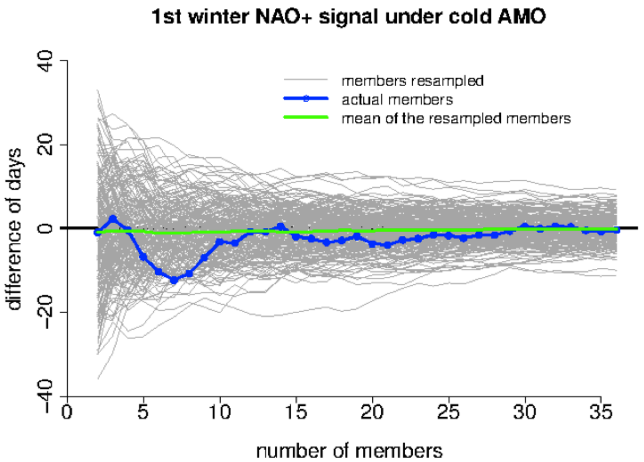
Actual members

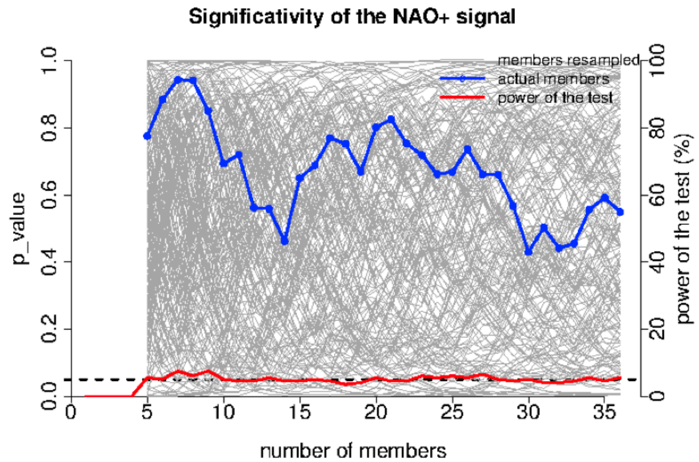
Members resampled

Volcanic signal / member mean (days)

P-value / power

Warm AMO





Weather regimes

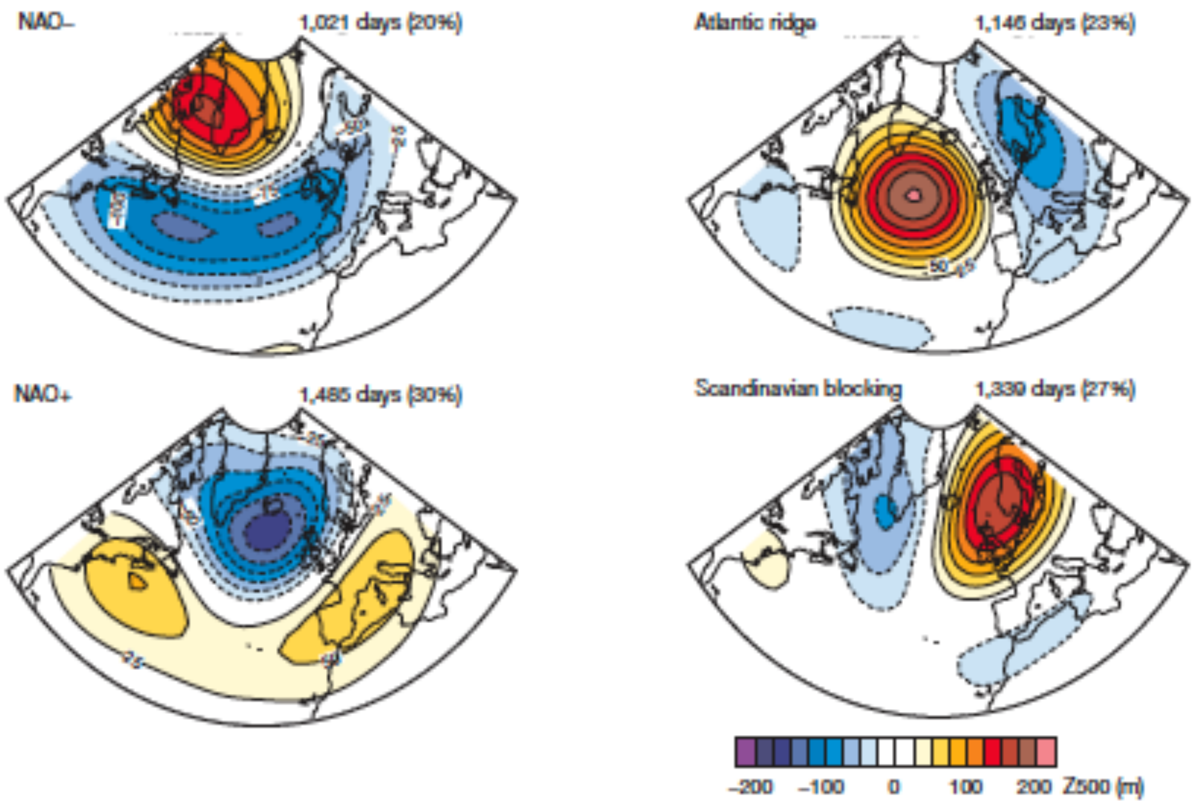
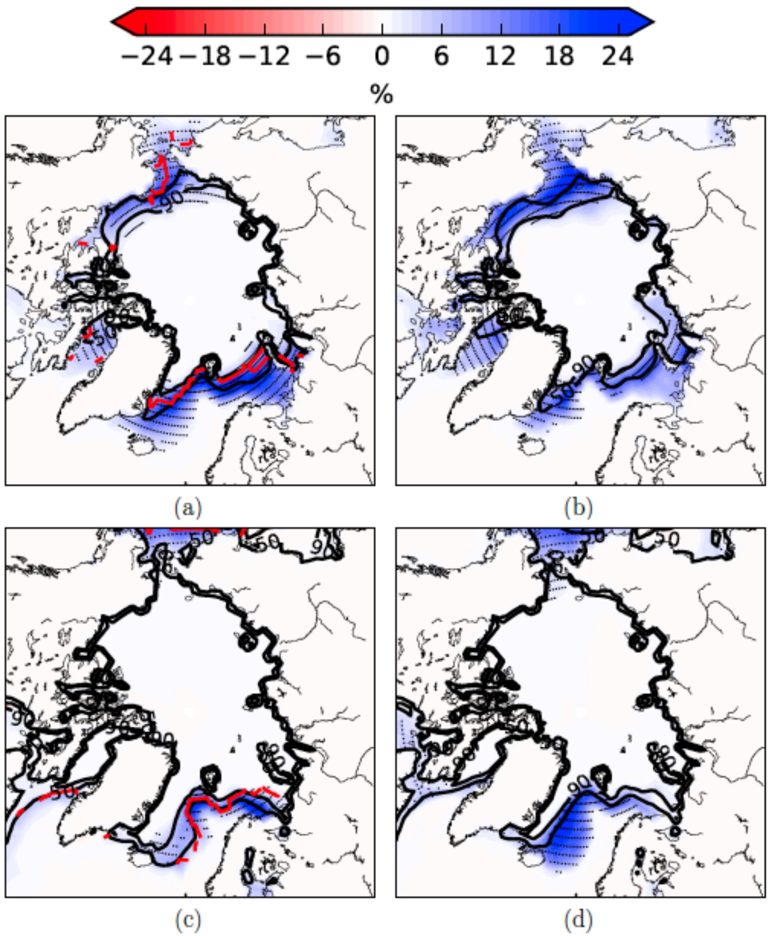


Figure 1 | Wintertime North Atlantic weather regimes. Centroids of the four weather regimes obtained from daily anomalous geopotential height at the 500-hPa altitude (Z500, colour) from the National Center for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) Reanalysis. Each percentage corresponds to the stated number of days and represents the mean frequency of occurrence of the regime computed over 1974–2007 from 1 November to 31 March. Contour intervals are 25 m. Details on the algorithm used for clustering are given in the Methods Summary and Supplementary Information.

From Cassou et al. (2008)

Sea-ice anomalies



Autumn

Winter

Cold AMO *Warm AMO*

Sea-ice anomalies simulated the third autumn and winter after a Pinatubo eruption. South of the red line, the response is stronger in the case of the cold AMO situation

The history of the discussion

→ The NAO is the main mode of variability in the North Atlantic, with strong impact on the European climate
→ Volcanic eruptions can have strong impacts on the climate system, in particular on the European climate
→ How do the NAO respond to volcanic eruptions?
→ The two winters following the Pinatubo eruption were typical from strong positive NAO conditions.

→ First concept of mechanisms: Stenchikov; Robock et al. 2000
→ Observations: last eruptions over instrumental era.
→ Millenium observations
→ Update of the model results: Barnes et al., Swingedouw et al.
→ EC-Earth forecasts
→ aim of the study; sensitivities experiments to check the impact of the climate conditions and to evaluate the signal/noise ratio.
→ Two parts: T and U response, AMV modulation
→ Noise
→ Conclusions